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Military, Charter, Unreported Domestic Traffic and General Aviation 1976, 1984, 1992, and 2015 Emission Scenarios

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ACRONYMS

AESA	Atmospheric Effects of Stratospheric Aircraft
ASK	Available seat kilometers
AST	Advanced Subsonic Assessment
CIS	Commonwealth of Independent States
CO	Carbon monoxide
EI	Emission index
GA	General Aviation
GAMA	General Aviation Manufacturers Association
HSCT	High speed civil transport
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
MDC	McDonnell Douglas Corporation
NASA	National Aeronautics and Space Administration
NO_X	Nitrogen oxides
OAG	Official Airline Guide
RPK	Revenue passenger kilometers
US	United States
SASS	Subsonic Assessment
THC	Trace unburned Hydrocarbons

1.0 EXECUTIVE SUMMARY

This report describes development of databases estimating aircraft engine exhaust emissions' for the years 1976 and 1984 from global operations of Military, Charter, historic Soviet and Chinese, Unreported Domestic traffic, and General Aviation (GA). These databases were developed under the National Aeronautics and Space Administration's (NASA) Advanced Subsonic Assessment (AST) contract NAS1-20268, Task Assignment 14. These databases will be available for atmospheric modeling studies being conducted by the Atmospheric Effects of Aviation Project (AEAP) investigation, an on-going, joint government-academia-industry research effort with multinational contributors.

McDonnell Douglas Corporation's (MDC), now part of the Boeing Company participation in the AEAP investigation has previously included creation of engine exhaust emissions' databases for the baseline year of 1992 and a 2015 forecast year scenario. Since their original creation (Ward, Reference 1,1994 and Metwally, Reference 2, 1995), revised technology algorithms have been developed. Additionally general aviation databases have been created and all MDC emission inventories have been updated to reflect the new technology algorithms. Summary results of this effort are provided in this report.

Revised data (Baughcum, Reference 3, 1996 and Baughcum, Reference 4, 1996), for the scheduled inventories have been used to provide an overall perspective of the total aviation emissions forecasts. The following eight figures present global results of two historic years (1976 and 1984), a baseline year (1992) and a forecast year (2015). Since engine emissions are directly related to fuel usage, an overview of individual aviation annual global fuel use for each inventory component is shown in Figure 1. In the baseline 1992 scenario year, aviation is estimated to have used an average 380 million kilograms of fuel per day, of which the Military component used approximately 18 percent. The 1992 scenario Charter and Unreported Domestic traffic (scheduled aviation within the former CIS, Eastern Bloc and China) are projected to represent respectively 5 and 6 percent of total aviation usage. The GA component (incorporating business jets, turboprop, light aircraft and civilian helicopters) is estimated to have consumed only 3 percent of aviation fuel in 1992.

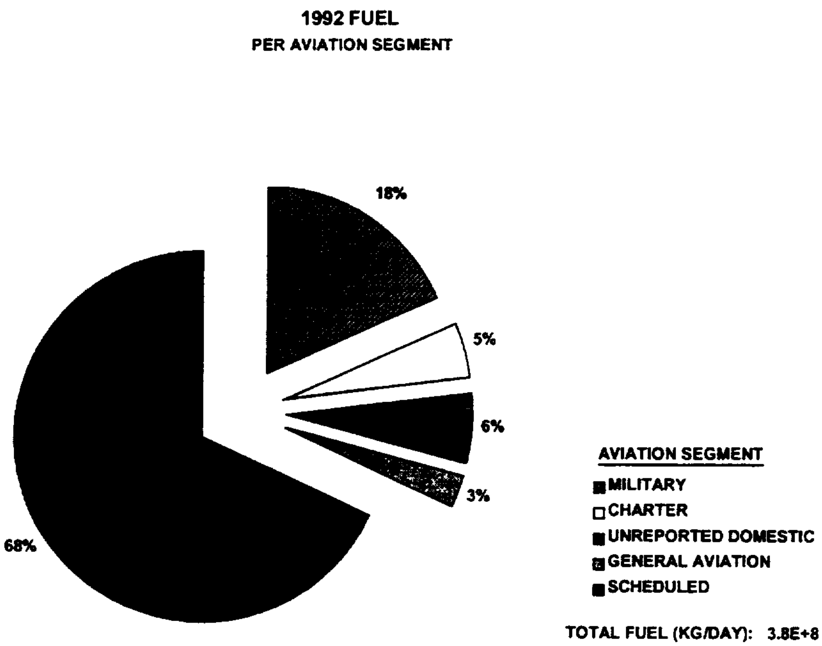


Figure 1 Comparison of fuel useage by aviation segments in the baseline 1992 scenario year

A comparison of the baseline 1992 scenario contributions for each of the three exhaust emission constituents (NO_X, CO, and trace unburned Hydrocarbons) created by individual inventory components are provided in Figure 2, Figure 3, and Figure 4. As shown in these figures, aviation emission constituents are dominated by the Scheduled airline component with its large aviation fuel budget. In 1992 an average 4.6 million kilograms per day of aviation NO_X are produced, of which the MDC military component contributes 14 percent, unreported domestic 6 percent, charter 5 percent, and general aviation 3 percent. Aviation was projected to have produced an average 4.3 million kilograms per day of CO in 1992. This constituent budget is somewhat more evenly distributed. Production of CO within the GA component is significant due to a large piston engine fleet with high CO production characteristics. The trace hydrocarbon (THC) aviation production in 1992 was projected to be an average 0.9 million kilograms per day. The THC contributions exhibit similar distributions to those shown by CO due to the piston engine fleet within GA.

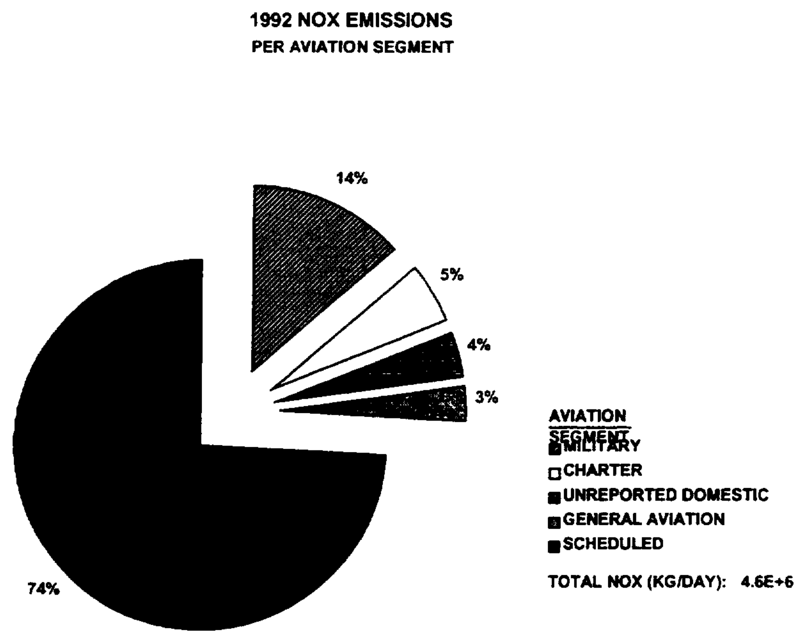


Figure 2 Comparison of individual aviation segments to total aviation NO_X in the baseline 1992 scenario year

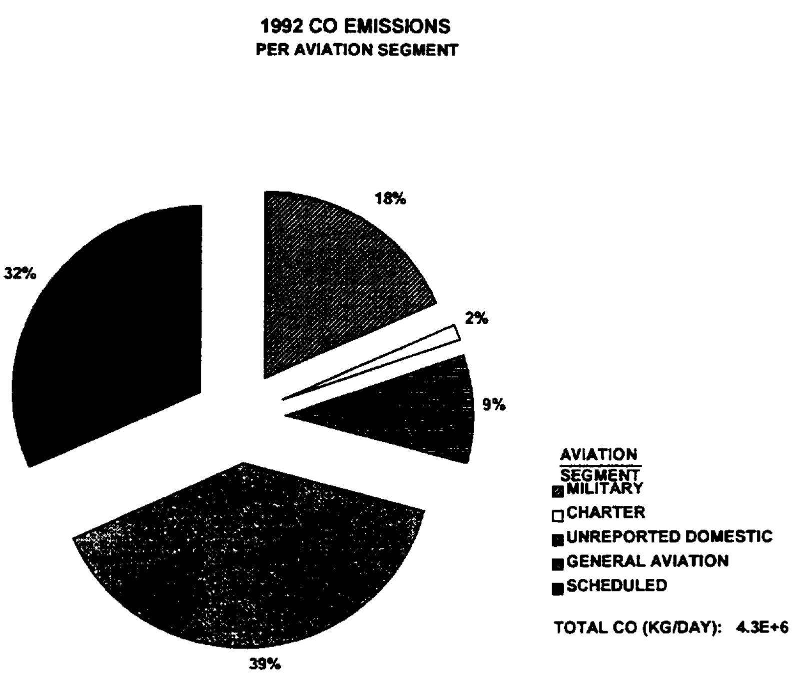


Figure 3 Comparison of individual aviation segments to total aviation CO in the baseline 1992 scenario year

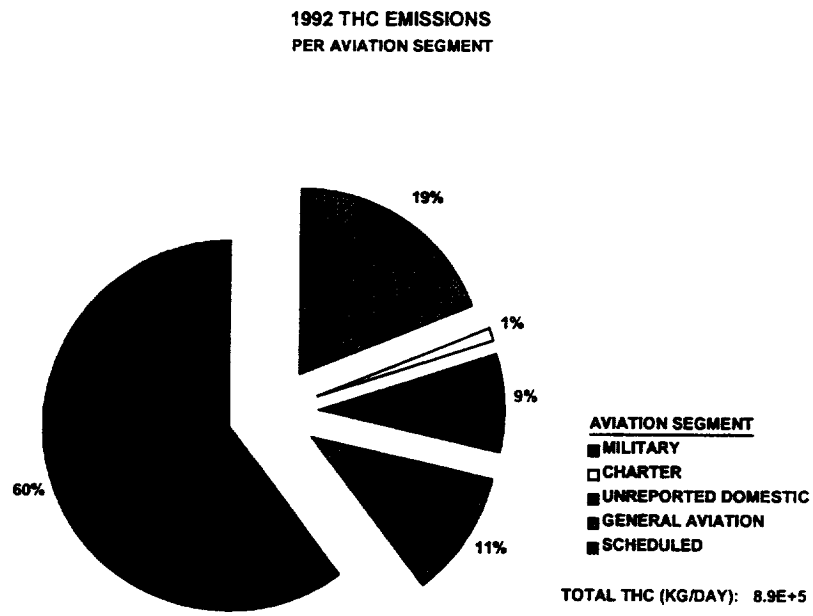


Figure 4 Comparison of individual aviation segments to total aviation THC in the baseline 1992 scenario year

Similar comparisons are provided in Figure 5 through Figure 8 for the forecast 2015 scenario. Fuel usage is dominated by the Scheduled commercial sector using over 80 percent of an average 850 million kilograms of fuel consumed per day by aviation in 2015. The Military component in 2015 represents only 7 percent of this total. This is primarily a result of the reduction in world inventories during the decline and conclusion of the Cold War and declining government funding. By the 2015 forecast year, Charter and Unreported Domestic traffic components are projected to represent respectively 4 and 5 percent of the aviation fuel. The GA component exhibits a general slow growth following the economic decline in 1992 and is forecast to represent 2 percent of the total aviation fuel used in 2015. Relative individual emission percentage contributions for the 2015 scenario for Charter, Unreported Domestic, and GA components remain similar to those in 1992, but are lessened as a result of the ascendancy in scheduled aviation contributions.

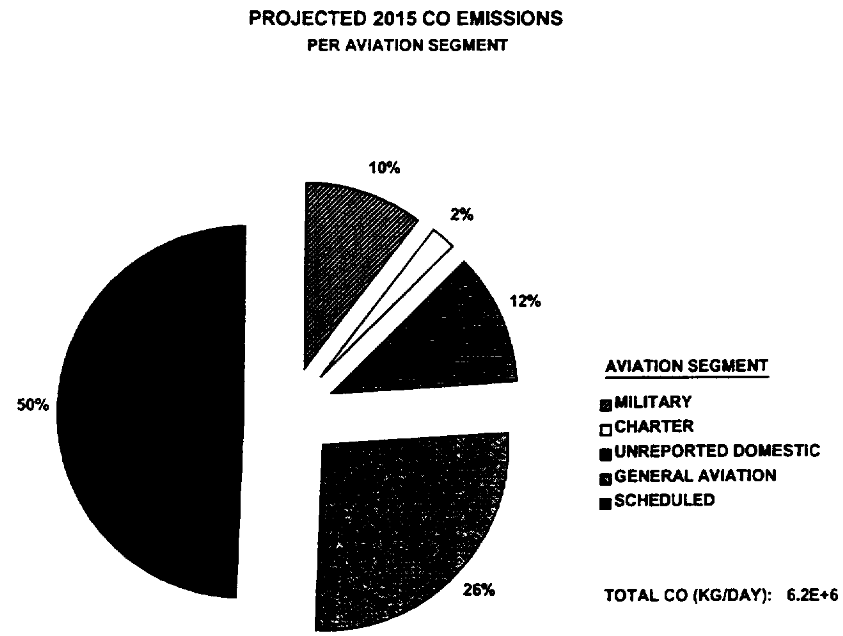


Figure 7 Comparison of individual aviation segments to total aviation CO in the forecast 2015 scenario year

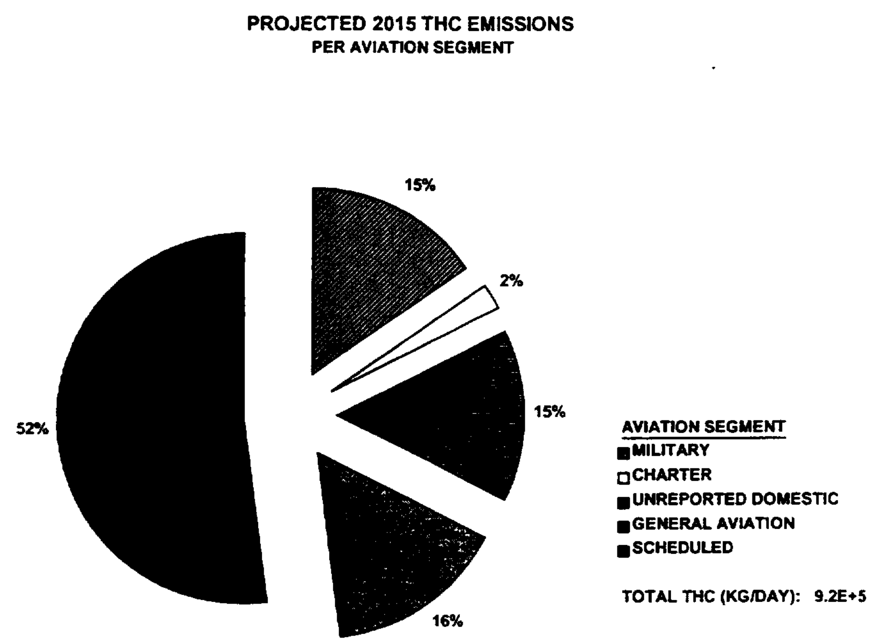


Figure 8 Comparison of individual aviation segments to total aviationTHC in the baseline 1992 scenario year

An overall perspective of the four scenario years is provided in Figure 9 through Figure 12. For each of the four scenario years considered, 1976, 1984, 1992 and 2015, the military component

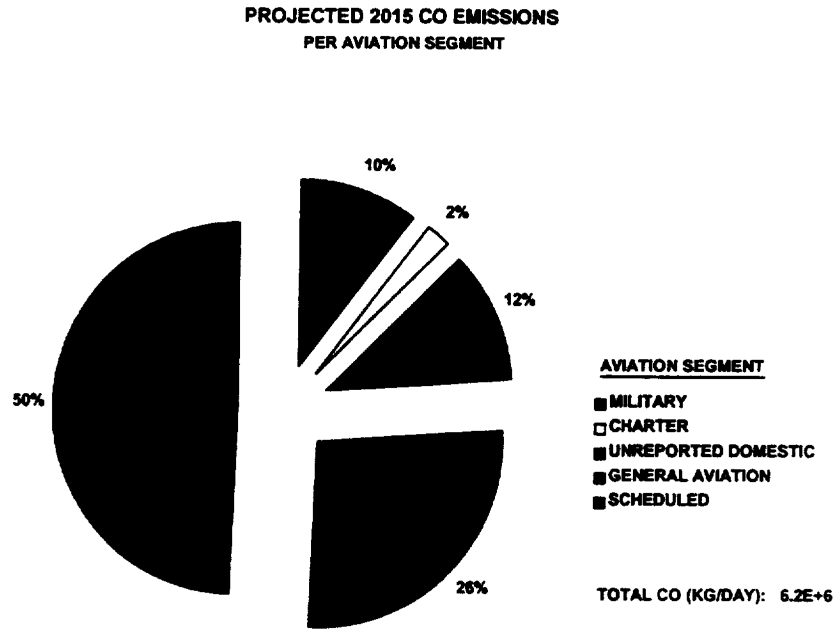


Figure 7 Comparison of individual aviation segments to total aviation CO in the forecast 2015 scenario year

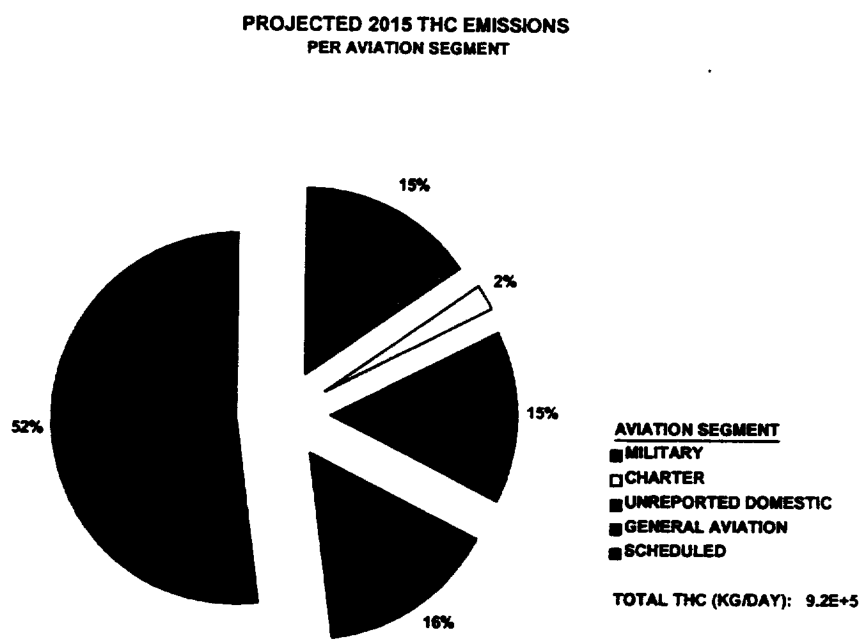


Figure 8 Comparison of individual aviation segments to total aviationTHC in the baseline 1992 scenario year

An overall perspective of the four scenario years is provided in Figure 9 through Figure 12. For each of the four scenario years considered, 1976, 1984, 1992 and 2015, the military component exhibits a continuous decline in annual fuel burn from reduction in world inventories during the subsiding of the Cold War, and an associated decline in government funding. The Charter and Unreported Domestic Traffic components during each scenario year reflect an increase in fuel usage. These two components reflect growth in revenue passenger kilometers (RPK). The 1992 scenario year exhibits a minor decline for Charter attributable to an adverse economic climate and the after effects of the Gulf War in that period. The GA component exhibits a general slow growth following the economic decline around 1992.

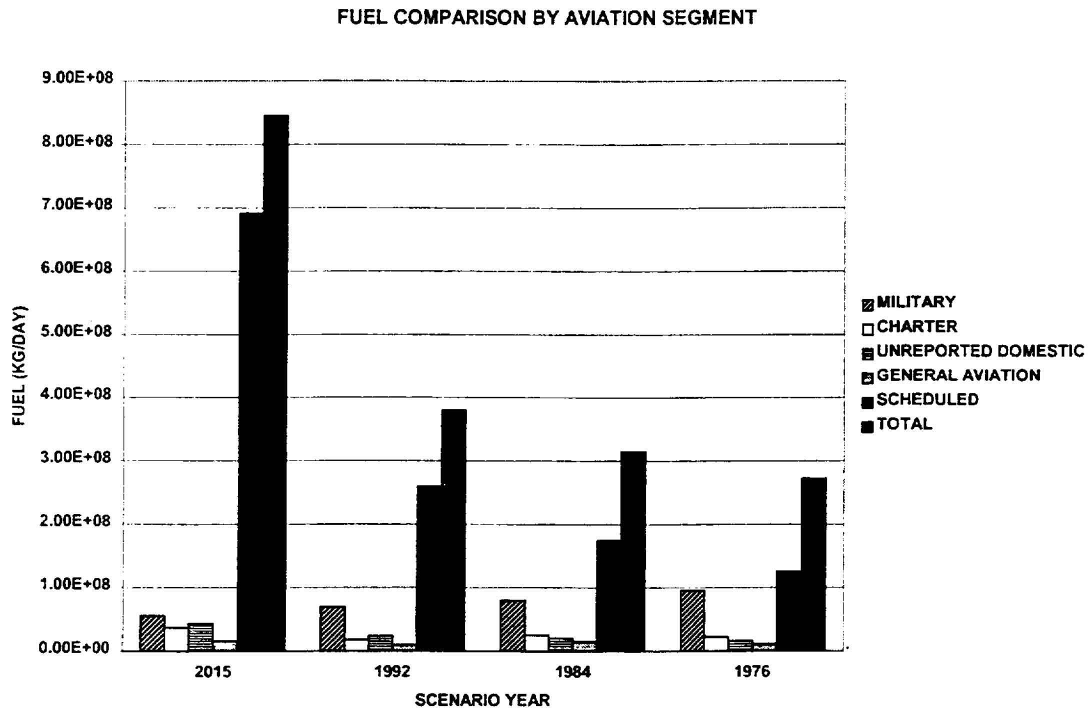


Figure 9 Fuel comparisons by component for each of the scenario years

A comparison of the annual totals for each of the emission constituents created by individual inventory components is shown below. The largest MDC contributor, the Military component reflects the diminishing fuel usage previously described. The 2015 annual projection for NO_X is approximately 80 percent of the 227 billion grams inventoried annually in 1992. Both the Charter and Unreported Domestic component emissions parallel the increases in fuel usage. In 1992, the Charter component produced 86.8 billion annual grams of NO_X , and is projected to increase to 185 billion grams in 2015 annually. The Unreported Domestic component approximately doubles NO_X, production during this same period, increasing from 64.7 billion annual grams in 1992 to a projected 117 billion annual grams in 2015.

The GA produced a total of 52.7 billion grams of NO_X, in 1992. A slow growth in overall GA activity yields a NO_X, production in 2015 of 70.4 billion grams annually. This component however is a significant element in the production of CO emissions providing over 39 percent of the CO produced by all aviation in 1992. GA during 1992 produced 614.1 billion grams of CO and is expected to slightly decrease to 598.6 billion annually in 2015, representing 26 percent of CO forecast to be produced by all aviation. This major production and stratification of CO at lower altitudes is attributable to the GA piston sub-component.

Boeing used a conservative approach in development of the 2015 GA scenario. Boeing recognizes that both NASA and the GA industrial community are currently on an engine development path to drastically reduce piston engine type CO and THC emissions. Among the goals of this development are to reduce both CO and THC emissions to respectively less than 2 and 1 percent of that produced by current piston engine technology. These engines are also projected to be retrofitable to current aircraft, and significantly improve both aircraft operational and economic performance.

Although the technology development for these engines are targeted to be completed by 2002, and possible initial fleet introduction in 2005, for the purposes of this study assumptions regarding rate of fleet replacement were considered far too speculative. There was no clear consensus of opinion within the GA community on this matter. Overall 2015 market penetration into the piston class of an advanced technology engine, using standard historical trends, was considered high risk. Such factors as initial certification dates, production rate forecasts, and both market acceptance and economics have significant variability. The Boeing conservative approach assumed no significant market penetration and hence no effective piston EI change. It is recognized however the GA piston fleet composition may experience a dynamic change resulting in major reductions in emissions. It is also suggested that piston fleet size would probably be increased in the aggressive technology change approach. Advanced aircraft initially would not directly replace existing piston aircraft, thereby creating a net inventory gain. In the Boeing scenario the 1992 and 2015 piston fleet sizes remained essentially unchanged.

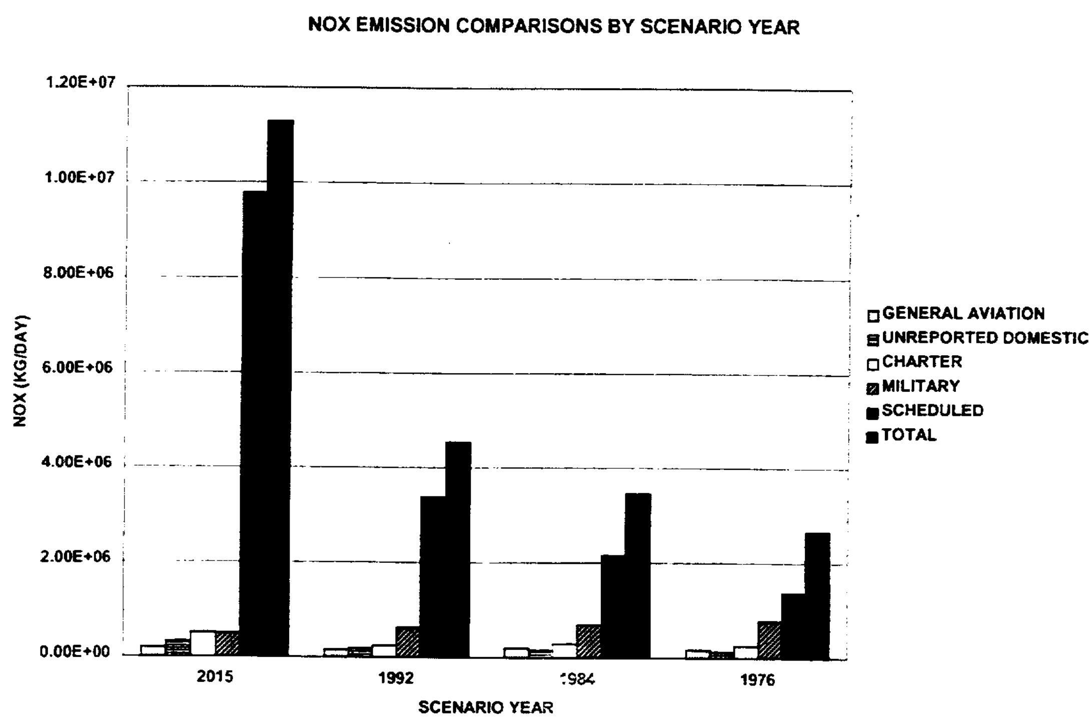


Figure 10 Comparisons of component NO_X for each of the scenario years

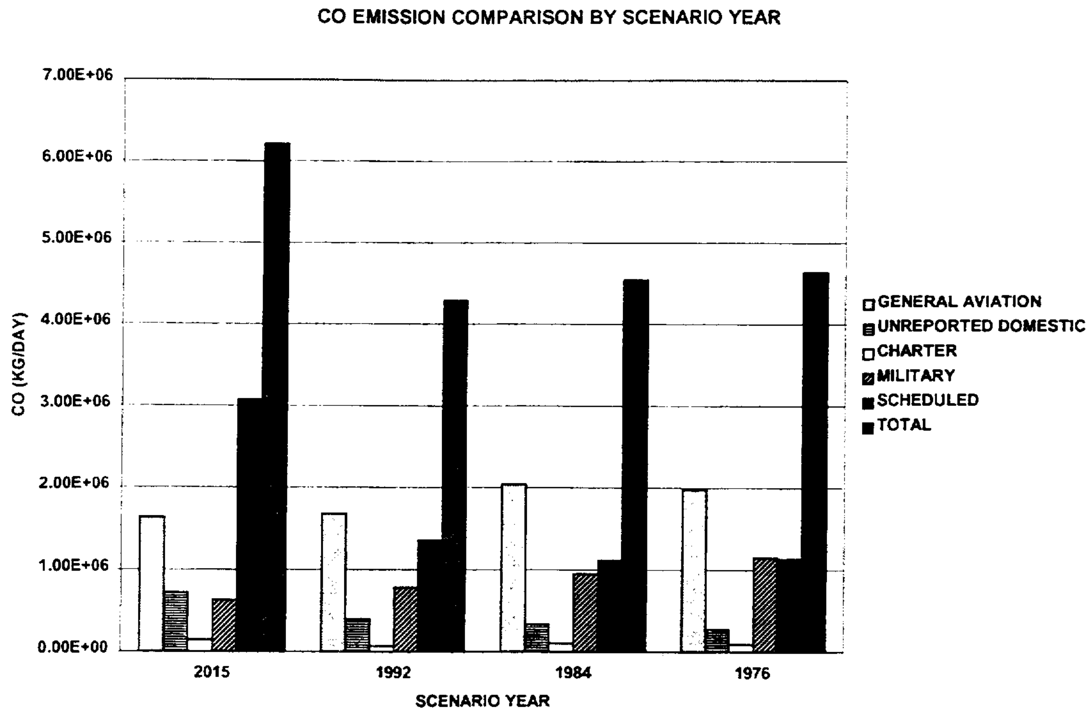


Figure 11 Comparisons of component CO for each of the scenario years

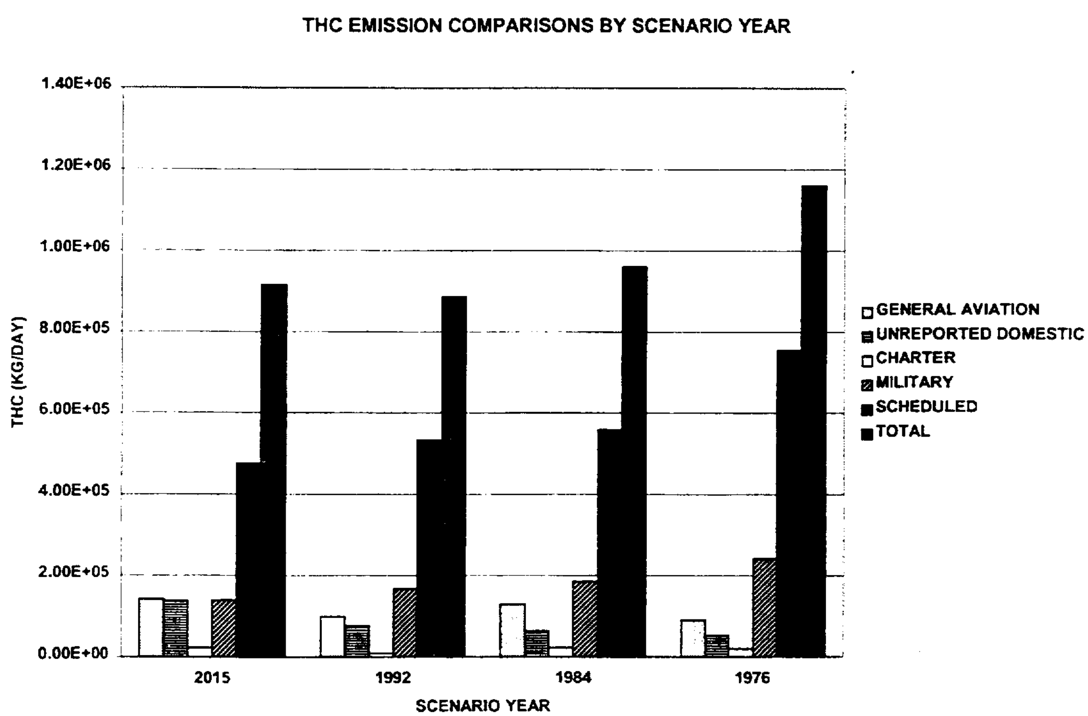


Figure 12 Comparisons of component THC for each of the scenario years.

2.0 INTRODUCTION

The NASA AST subsonic emissions assessment (SASS) program is an on-going, joint government-academia-industry research effort with multinational contributors. Started in 1990, the program attempts to reduce some of the uncertainties surrounding the effects of aviation on climate change. The former MDC, now part of the Boeing Company, participation in the subsonic assessment of has included developing several aircraft engine emissions databases for year a 1992 baseline scenario, two historical years (1984 and 1976) and a forecast year 2015. This report supercedes data presented in previous MDC published reports on this subject (Ward, Reference 1, 1994, Metwally, Reference 2, 1995, and Wuebbles, Reference 5, 1993), as methodologies and technological aspects have been refined and improved. These databases, as before, represent various components of aircraft categories and consist of a global, three-dimensional grid, one degree latitude by one degree longitude by one kilometer altitude. The grid's cells contain aggregate estimates of the annualized fuel burn and levels of engine exhaust emission constituents, specifically oxides of nitrogen (NO_X), carbon monoxide (CO) and unburned trace hydrocarbons (THC). These database files have been delivered to NASA Langley Research Center electronically. They can be obtained by sending a request to the Atmospheric Sciences Division, MS 401, NASA Langley Research Center, Hampton VA 23681-0001, or by contacting Karen H. Sage at sage@uadp2.larc.nasa.gov .

The methodology employed was a multi-step process within which there are a series of simplifying assumptions. This methodology has previously been (Baughcum, Reference 2). The following abstract of previous documentation provides an overview of the methodologies.

3.0 METHODOLOGY COMMON TO ALL COMPONENTS

The first major step is obtaining an inventory of the aircraft types and quantity of operational aircraft in use for specific mission. A mission type is considered in a general context to having applicability to both military and commercial aircraft operations, and refers strictly to how an aircraft is operated between two locations. Aircraft in these inventories are characterized in terms of design mission(s), weights, configuration, including engine types and number of engines.

For specific aircraft in each inventory component, engine characteristics, including thrust rating and fuel consumption rate, appropriate to the individual aircraft were defined. The combination of engine and the aircraft's characteristics established the specific performance capabilities.

The next step within the process required defining route flight profiles. These individual routes specify the origin, destination, action points (where the aircraft change's course, or varies altitude/speed), and flight frequency. Flight frequency, or utilization, was measured either by flight hours or trips per year.

3.1 GENERIC AIRCRAFT

The Military, Charter, Unreported Domestic, and General Aviation aircraft inventories represent the types and quantities of operational aircraft in use for a specific mission and are established or forecast from a variety of sources. Developing realistic mission fuel consumption and engine exhaust emission estimates is impossible without detailed performance data on each aircraft type. Therefore generic aircraft were used to develop the scenario emissions' databases.

Specifically, one or more notional aircraft was used to represent all aircraft in a component's inventory in the performance of a particular mission. A component's generic aircraft were composite representatives of characteristics of the actual aircraft performing the mission and in fact, are real aircraft types (for which accurate performance data are available) with assigned fuel burn multipliers. A fuel burn multiplier is a weighted-average function, applied by mission category, utilizing aircraft maximum gross weight, engine quantity, rated thrust, and thrust specific fuel consumption. The product of the fuel burn multiplier and the actual aircraft's fuel consumption rates approximates the desired performance of the generic aircraft. Other characteristics considered in developing the generic aircraft included wing configuration, performance (range and capacity), and age. Figure 13 shows the generic aircraft development process for the military component but is representative (in functionality) for all components. This process is largely subjective and limited by the availability of real aircraft performance data. Finally, the generic aircraft's engine exhaust emission indices are assumed to be equal to the engine exhaust emission indices of the real aircraft upon which the generic aircraft is based. Details of these processes are described within the references (Ward, Reference 1, 1994, Metwally, Reference 2, 1995, and Baughcum, Reference 3, 1996).

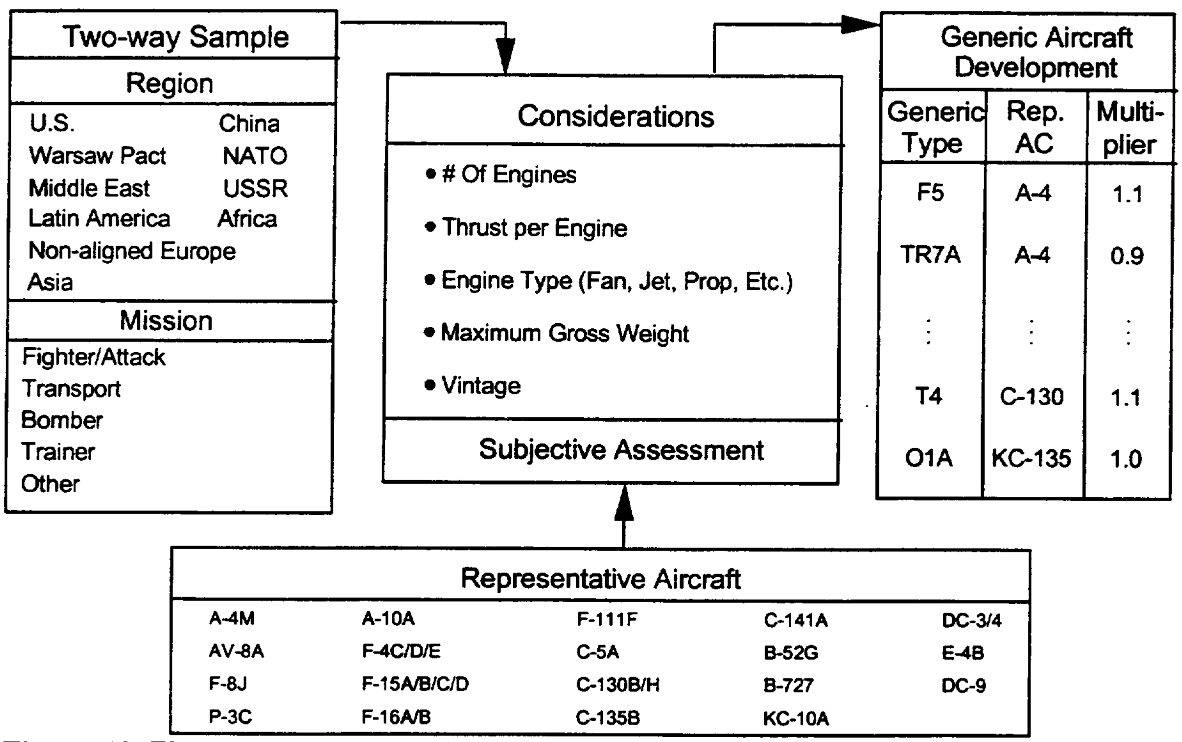


Figure 13 The military component generic aircraft development process. The charter, unreported domestic domestic, and general aviation traffic components use a similar approach.

3.2 AIRCRAFT ENGINE EMISSION INDICES

An engine emission index (EI) measures the mass of exhaust constituent produced per mass of fuel burned (measured in grams/kilogram), and is typically depicted as a function of engine power setting or fuel flow rate. The relative concentrations of nitrous oxides (NO_X), carbon monoxide (CO) and trace hydrocarbons (THC) vary over the flight profile. Reported ICAO engine test data is limited to engine power settings (fuel flow rates) common to the landing-takeoff cycle, i.e. taxi/idle, takeoff, climb,descent and approach. Derivation of intermediate emission indices at other mission fuel flow rates, was performed by MDC using a simple linear interpolation of ICAO fuel flow rates at reported test emissions. The results of these actions are described in MDC Contractor Reports 19345 and 4684 (Ward, Reference 1, 1994 and Metwally, Reference 2, 1995). Substantial previous work (Pace, Reference 6, 1977, Sears, , Reference 7, 1978, ICAO, , Reference 8, 1989, and Teledyne Continental Motors, Reference 9, 1976) has been accomplished to document emission indices for a wide variety of commercial and military jet engines. A methodology to describe an engine EI operating at conditions other than sea level testing, is referred to as the Boeing Method 2 (Baughcum, Reference 3, 1996). This development occurred after the initial MDC databases were produced. The new methodology implements correction equations used for fuel flow and emission indices, which explicitly account for ambient temperature, humidity, pressure and Mach number. This method employs logarithmic interpolation to determine emission indices at operational flowrates rather than the originally implemented simple linear interpolation. This current report documents the finalized version of incorporating the full impact of employing the Boeing Method 2 methodology. An example of the changes in EI for the Military component engine E11 are shown in Figure 14, Figure 15, and Figure 16 for each emission type. For this example engine at cruise conditions, both the CO and THC EI are significantly reduced from 69.0 to 20.2 and 70.3 to 8.7 respectively. The NO_X EI is slightly elevated increasing from 3.1 to 5.3 at cruise conditions. The finalized mission indices for all engine types used within each component are provided within Appendix A.

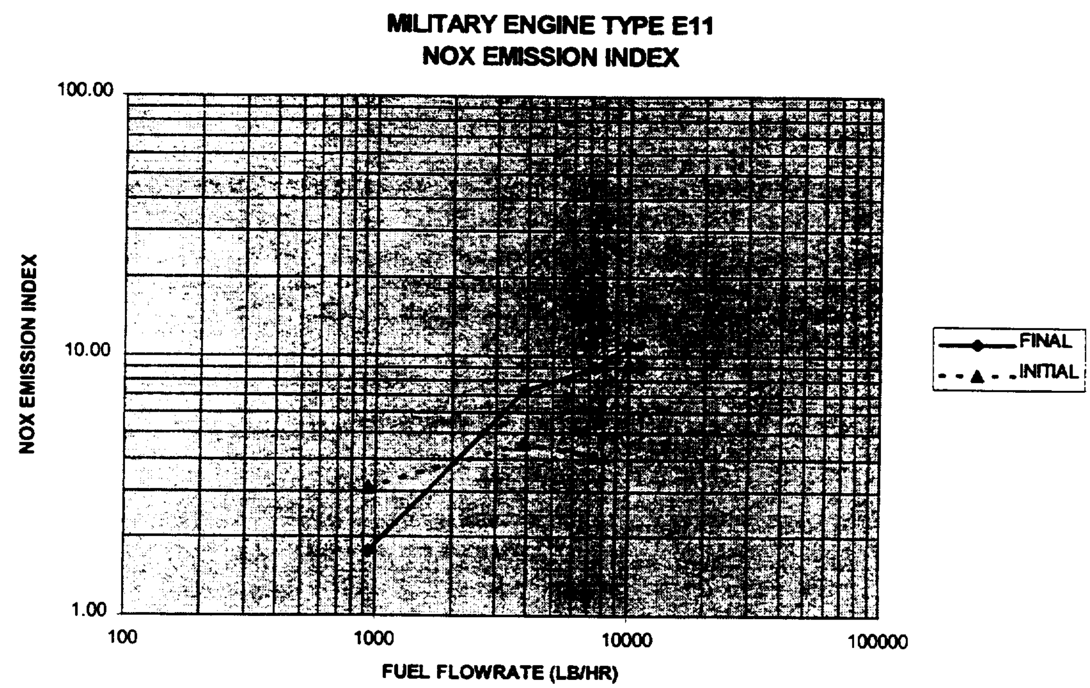


Figure 14 Emission Index comparisons NO_X for following full implementation of Method 2.

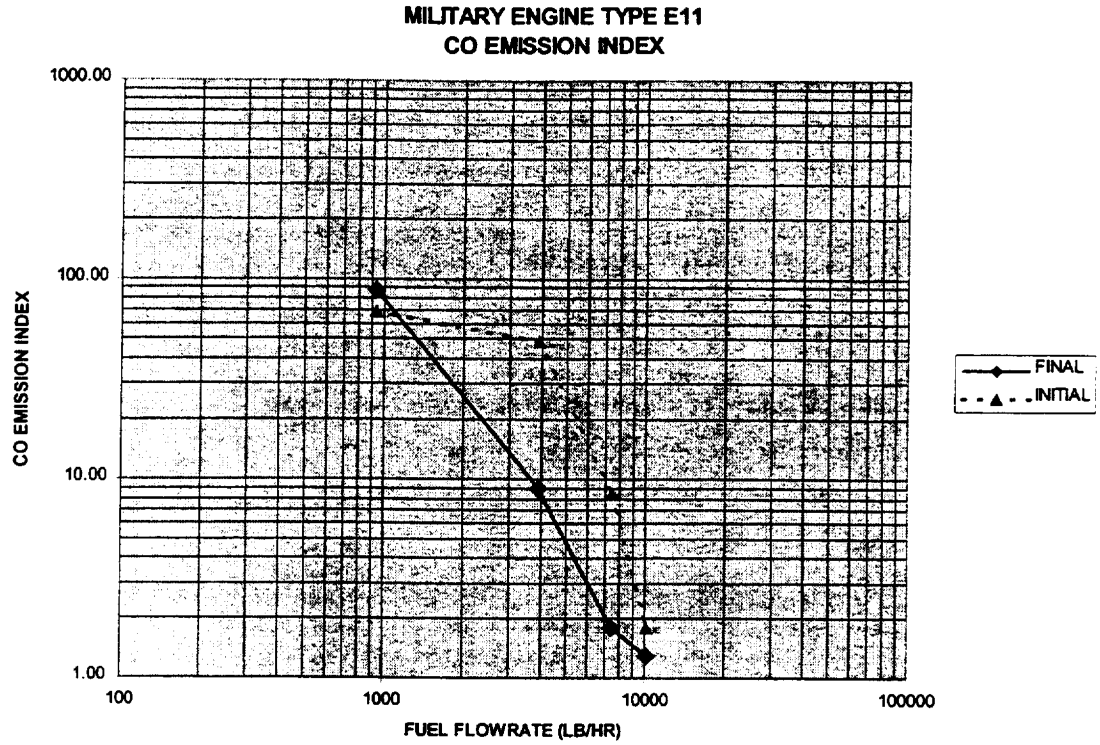


Figure 15 Emission Index comparison for CO following full implementation of Method 2

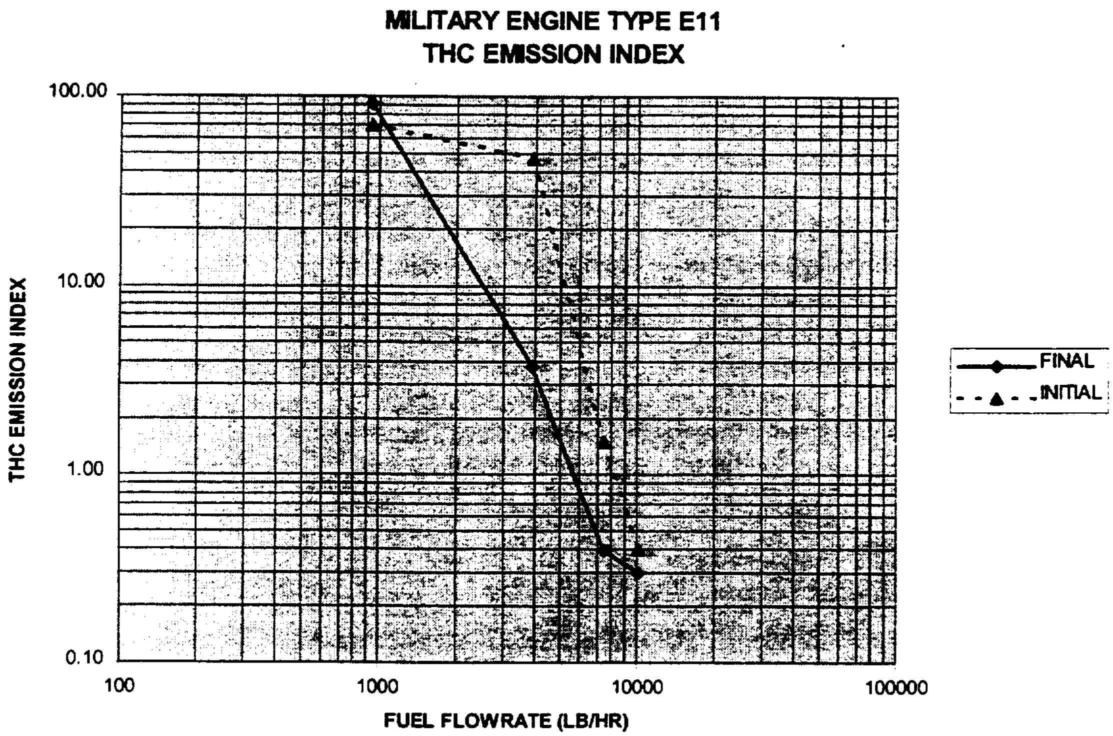


Figure 16 Emission Index comparisons for THC following full implementation of Method 2

3.3 GRID GENERATION

Annual fuel consumption estimates are resolved into a global three-dimensional geographic grid for every unique route/aircraft combination after decomposing the individual mission profile into a position, distance, time, fuel, and altitude data set. The fuel consumed on any flight segment traversing one or more grid cells is then linearly allocated within these cells.

Each active grid cell's fuel burn estimate for a unique aircraft type is multiplied by its constituent EI for each flight level. The grid generation process occurs for all missions of a generic type and then summed by cell to produce an aggregate grid. Each aggregate grid is then summed to produce the component emission database (i.e. military, charter, etc.).

4.0 COMPONENT UNIQUE METHODOLOGIES

The following sections discuss development of each component emission database with specific emphasis toward methods unique to a component.

4.1 MILITARY COMPONENT

The military component inventories include aircraft assets from all branches of the military including guard, reserve, and paramilitary forces where applicable. Mission, country, and region categorize these inventories.

Five mission categories were identified (fighter/attack, transport, bomber, trainer, and miscellaneous/other) within which generic aircraft were introduced. The fighter/attack mission category included those aircraft whose primary mission role is air-to-air combat and/or ground attack and air defense. Aircraft used in strategic and tactical transport, liaison, executive transport, or aeromedical evacuation roles composed the transport mission category. The transport mission category also included aerial refueling (tanker) aircraft except for the United States (US) and CIS in which case the aerial refueling mission was a separate category. The bomber mission category included both long-range and short-range bombers. The miscellaneous/other category contained maritime patrol; airborne electronic platforms performing electronic warfare, electronic intelligence, and electronic countermeasures' missions; reconnaissance and surveillance; and special operations aircraft. The miscellaneous/other category however was exclusive of helicopters. Comparison of regional inventories to the baseline 1992 regional types was performed. Where significant inventory changes in the overall character of a regional mission category occurred, applicable adjustments were made to the fuel burn multipliers.

Basing of military aircraft was performed by considering all of a region/alliance/country group's military aircraft at a single location within the political boundaries of the group (Air Force Magazine, Reference 10, 1991 and DMA, Reference 11,1991). Except for the US, CIS, and China, all of a country's military aircraft was based at one or two centrally located airfields within the political boundaries of the country. Those aircraft deployed to a foreign territory were based in the host country.

The US operates the world's second largest fleet of military aircraft, accounting for approximately twenty percent of the global total depending on scenario year. For basing purposes, the US was subdivided into five regions and one or more locations selected within each region to station the generic aircraft. Each region's allocation of aircraft, by mission type, approximated the actual mix of operational aircraft assigned to military bases contained in the region. Some US Air Force and Navy aircraft were located in foreign territories to reflect unit deployments.

Likewise approximately twenty percent of the world's military aircraft are owned by the former CIS. The sizes of the CIS military aircraft fleet and the CIS land mass suggested a more accurate estimate of the CIS contribution would be obtained by basing its aircraft in a more representative fashion than through central basing. The former CIS located its military assets among eight entities called fleets, front, or strategic directions. Each of these entities was further divided into military districts (within the former CIS) and groups of external forces (forces stationed in Warsaw Pact countries). These forces were allocated, by mission type, to the eight entities approximately in proportion to the actual basing of military aircraft. Then, a single, central location within each entity was selected to be the base from which all missions would originate. Aircraft representing strategic aviation assets not specifically assigned to a strategic direction were evenly dispersed among the entities.

China, with roughly 10% of the world's military aircraft, is similar to the CIS, containing military regions that are further subdivided into military districts. Ten military regions were assumed, with air divisions comprising bomber, fighter/attack, transport, and other aircraft assigned within the regions. A single, central location within each region was selected to station the air divisions. Generic aircraft representing China's naval aviation assets were equally divided and based at a single shore facility within each fleet's operating area.

A generic military aircraft's mission profile included a takeoff from the origin, an initial climb to cruise altitude, a fixed distance cruise segment along a great circle route, and, depending on the mission type, either a landing and subsequent return to the origin, a period of combat training maneuvers, and a subsequent return to the origin. All military air traffic component missions began and ended at the same location. Four randomized headings, indicating the initial flight direction from the origin, were generated for each generic aircraft type. Allowable headings were restricted to assure flight, as much as possible, occurred over a group's own territory.

Aircraft utilization rates (flight hours per year) were scaled off historical US Air Force planning factors (Ward, Reference 1, 1994). Little unclassified data existed to substantiate non-US military aircraft utilization. As a result, gross level approximations were assumed which express non-US utilization rates as a percentage of US utilization rates. The product of the inventory count, authorized operational aircraft, and utilization rates, yielded the flying hours per year for each region/alliance/country group and mission category. Division of the flying hours per year by the appropriate generic aircraft mission time yielded an annual frequency (missions/year) for the generic aircraft type.

4.2 CHARTER AND UNREPORTED DOMESTIC TRAFFIC COMPONENT

This section describes the methods used for syntheses of representative air traffic network models, the generic aircraft used to simulate operations, and the development of fuel burn and engine exhaust emissions' estimates for the charter and unreported domestic traffic components. The unreported domestic traffic refers to the scheduled domestic traffic in the CIS, China, and Eastern Europe not reported in the Official Airline Guide (OAG).

An origin-destination city (or airport) pair defined each route. For both the charter and unreported domestic traffic components, the most frequently traveled city pairs were identified (using either revenue passenger kilometers (RPK) or available seat kilometers (ASK). All component air traffic was then allocated to these sets of city pairs.

More than 90% of charter air traffic originate in Europe and North America with significantly smaller contributions from Latin America, Middle East and Africa, and the Far East. As a result, the global charter air traffic network model was constructed by merging European and North American regional traffic network models. Of a possible 652 origin-destination city pair combination set only 298 origin-destination city pair combinations in the merged traffic network model were active; i.e. air traffic flows between the cities. Using RPK as the selection criteria, the top 100 origin-destination cities were selected as representatives for the entire charter network.

The former Russian carrier Aeroflot dominates the Unreported Domestic component. The Aeroflot domestic network structure therefore formed the nucleus of the Unreported Domestic air traffic network model. The domestic passenger flight schedule simulation developed by MDC contained 264 routes with a wide range of service frequencies. The top 86 of these routes were selected, based on service frequency, provided a network model adequately describing the geographical distribution of Aeroflot's domestic network. An additional five routes were included within the network to account for the remaining unreported Eastern European and Chinese domestic traffic.

Both the charter and unreported traffic component used generic aircraft paralleling the military emissions methodology. Ten generic aircraft engines were used for the charter component to model fuel burn and engine exhaust emissions; the unreported domestic traffic component employed three generic aircraft. Assignment of a generic aircraft to a·route was defined by the route's range and capacity requirements.

For each of the top 100 charter and 91 unreported domestic city pairs in the 1992 scenario, a single generic aircraft type, assigned by range and capacity, was assumed to carry all annual traffic on a great circle route between city pairs. The generic aircraft capacity dictates the number of flights that must be completed annually to carry all apportioned traffic. Two measures of effectiveness for commercial aircraft are the aircraft's block fuel and block time. Block fuel is the sum of ground maneuver fuel, climb fuel, cruise fuel, descent fuel, and approach fuel. Block time is the sum of the time required in performing these components. Block fuel and block time equations were developed for each generic aircraft as a function of great circle distance. These performance equations, together with the required number of flights, yielded annual estimates of fuel burn and aircraft hours for each route in the air traffic network models.

An aircraft's fuel burn on a route is not linear with distance. For the ground distance covered, an aircraft uses a relatively large amount of fuel in the initial climb. Similarly, an aircraft burns a relatively small amount of fuel while flying typical descent schedules. Taxi-out and takeoff operations concentrate fuel burn at the origin while approach, landing, and taxi-in operations concentrate fuel burn at the destination. Although fuel consumed during the initial climb and descent phase of flight depends on factors such as initial cruise altitude, final cruise altitude, takeoff gross weight and landing gross weight, constant amounts typical of each generic aircraft's class were assumed for both the climb and descent phases of flight. Therefore, these representative values for engine start, taxi-out, takeoff, climb, descent, approach, land, and taxi-in fuel burns were subtracted from block fuel. Similarly, representative climb and descent distances were subtracted from the great circle distance. The remaining block (or cruise) fuel was then linearly allocated over the remaining great circle distance.

Factors influencing an aircraft's cruise altitude including segment range, aircraft operating characteristics, type of cruise (step-climb, cruise-climb, constant altitude cruise, etc.), traffic, weather, and direction of flight. The methodology assumed aircraft were operated using either constant altitude cruise or cruise-climb profiles at altitudes representative of typical operations. These altitudes range from 15,000 feet for short range, twin-jet operation to 37,000 feet for long range, wide-body operation. All fuel was linearly allocated between the initial and final altitudes.

4.3 GENERAL AVIATION COMPONENT

This section describes the methods used to simulate generic GA operations, and the development of fuel burn and engine exhaust emissions estimates.

Four mission categories were identified (executive jet, turboprop, piston and helicopters) within which generic aircraft were introduced. Both the turboprop and piston categories were further subdivided into multi and single engine classes. The generic helicopter was similarly divided into piston and turbine sub-classes.

The basing of GA paralleled the military component. Aircraft were based in regional areas throughout the world. This segmentation process was based on the International Airline Transport Association (IATA) regions. A total of twenty global regions were defined. Except for North America, all regions' general aviation aircraft were located at one airfield. The North American continent was treated as a special entity due to its geographic size and quantity of aircraft. This region was further subdivided into 25 sub-regions each containing one airfield. All GA missions were depicted as beginning and ending at these airfields. Four randomized headings, indicating the initial flight direction from the origin, were generated for each generic aircraft type. Allowable headings were restricted so flight, as much as possible, occurred over a landmass.

Utilization for all forms of GA was determined by applying aircraft departure rates (departures per year, per region) using available ICAO data (ICAO, Reference 12 through Reference 22). The average distance flown was based on the reported average number of flight hours per departure. Performance data was developed from various source data or scaled from comparably sized commercial aircraft. The flight profiles were developed using estimated performance for typical fuel burn and distance during climb and descent to cruise altitude. Cruise flight conditions were also estimated data for typical altitude, speed and fuel burn rate.). Upon completion of the initial historical database build procedure, overall results were presented to representatives of the General Aviation Manufacturers Association (GAMA). A thorough review of their historical databases (GAMA, Reference 23 through Reference 28) and operational recommendations, resulted in an effective global downsizing of the active aircraft fleet and resultant in reductions in total fuel use and emissions.

Projections for the 2015 scenario year were developed using both the previously developed historical data and short range forecasts from both the FAA (Federal Aviation Authority, Reference 29, 1995) and GAMA (GAMA, Reference 23 1997). The same generic aircraft and emission indices were used for the 2015 scenario estimates. While there will be some sub-component fleet mix changes, it was assumed that retention of existing aircraft would remain high. Consequently no improvements in either fuel consumption or emissions were assumed. One operational change was introduced within the executive jet sub-class. The mission range for an executive jet was permitted to those required for intercontinental operations. General aviation airport origins previously employed were paired to represent these intercontinental routes. Executive jet projected 2015 operational growth was apportioned such that an average 30 percent of the executive jet fuel was dedicated to long range routes.

Trends in both individual sub-component fleet growth and utilization rates were projected from historic year inventory growth and available forecasts to the 2006 time frame. Shown in Table 1 are the projected 2015 inventories and inventories for each scenario year. During the 23 year period GA total inventory will grow by a total of 5.2 percent. The largest contributing component, piston propelled, will decline by 3 percent, while the remaining components are expected to grow by 76 percent.

Table 1 Global inventories of General Aviation aircraft for historic years of 1976, 1984, 1992 and forecast year of 2015.

YEAR	AMERICAS						
	NORTH	SOUTH	EUROPE	ASIA	AFRICA	OCEANA	TOTAL
2015							
PISTON	154003	28093	41837	9960	6989	15672	256555
TURBO PROP	8766	1524	1998	3431	752	1287	17758
EXECUTIVE JET	7827	301	1253	243	151	412	10186
HELO.	9562	1623	5988	7705	540	1571	26990
TOTAL - 2015	180158	31541	51077	21339	8432	18942	311489
1992							
PISTON	189348	19015	33154	7746	5292	10185	264740
TURBO PROP	5645	1014	1158	1117	298	419	9651
EXECUTIVE JET	4547	122	682	79	96	81	5607
HELO.	7742	1077	3973	1712	425	1042	15971
TOTAL -1992	207282	21228	38967	10654	6111	11727	295969
1984							
PISTON	268063	16715	29177	8559	4943	8326	335783
TURBO PROP	6901	880	755	751	216	209	9712
EXECUTIVE JET	3981	56	331	40	82	46	4536
HELO.	12133	832	2481	1069	391	641	17547
TOTAL - 1984	291078	18483	32744	10419	5632	9222	367578
1976							
PISTON	212449	13962	24797	8831	4312	1088	265439
TURBO PROP	3008	194	360	524	74	46	4206
EXECUTIVE JET	1907	54	264	10	43	16	2294
HELO.	7740	511	1669	661	215	495	11291
TOTAL - 1976	225104	14721	27090	10026	4644	1645	283230

5.0 COMPONENT SCENARIO RESULTS

Specific methodology inputs, resultant estimates of fuel burn and emissions for each scenario year, and a discussion of results are provided in the following sections for each component scenario considered.

5.1 MILITARY COMPONENT RESULTS

The Military component fuel burn and emissions are directly effected by the estimated available military inventories. As shown in Figure 17, the 1984 scenario year grew 17.5% to 56248 aircraft from the 1976 base year. The decline of the Cold War resulted in an approximate 5% decline to 53248 aircraft in 1992, and is projected to further decline to 51600 aircraft in 2015 (International Institute for Strategic Studies, Reference 30 through Reference 33). The combined inventories of the US and CIS during this period represented nearly 40% of the global inventories. Throughout these scenario years their combined inventories of bombers and transports represented 48% of the global inventory of this high fuel usage sub-element of the military component. Depicted in Figure 18 are the variations in historic regional inventories for each of the historic scenario years. During this time period, these combined inventories declined 2% in comparison to their respective global inventories. This impact on fuel use is further amplified due to the higher utilization rates and flying hours employed within these regions (USAF, Reference 34, 1989 and Ward, Reference 1, 1994). Further details of global historic inventories are provided in Appendix. A

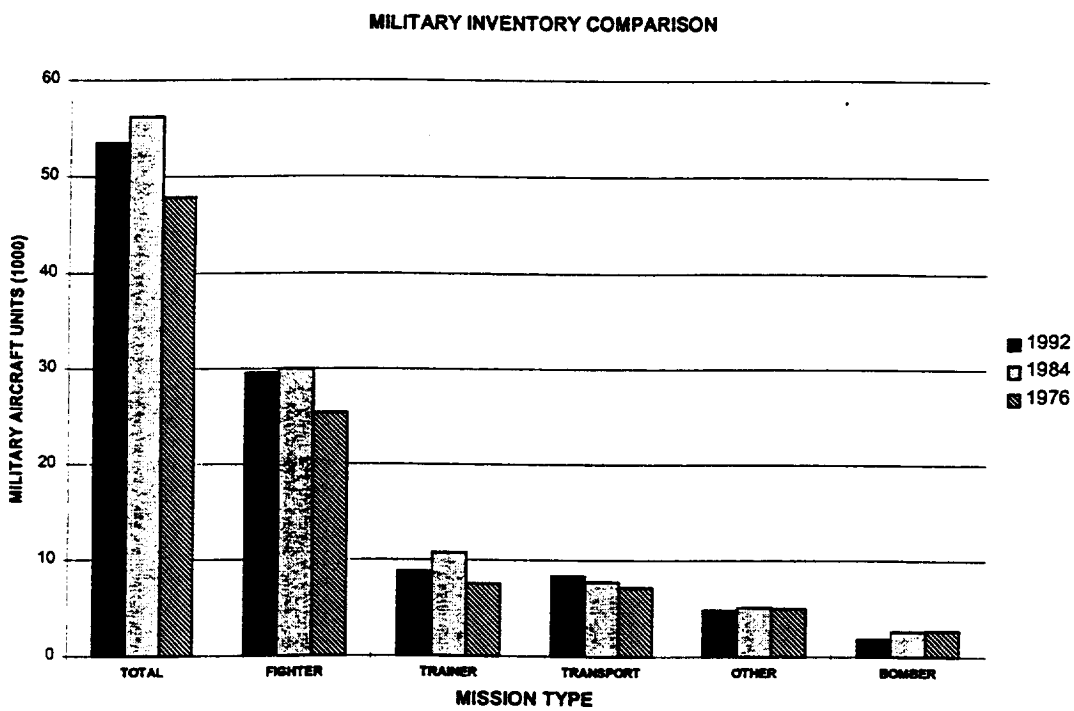


Figure 17 Global military inventories by mission type for the historic scenario years of 1992, 1984 and 1976

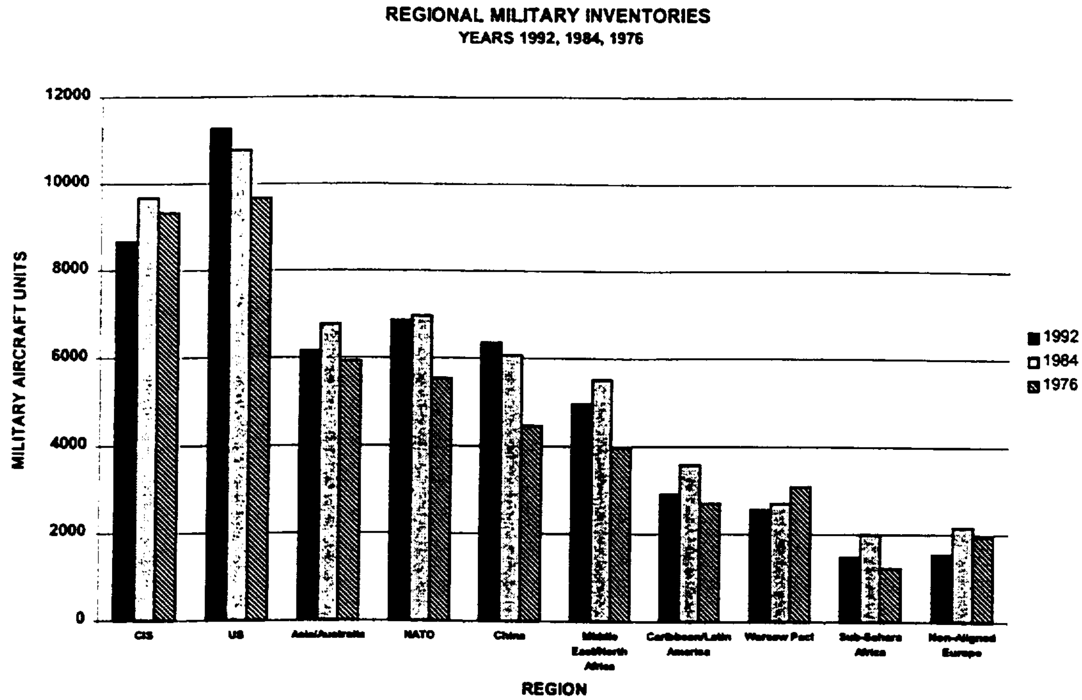
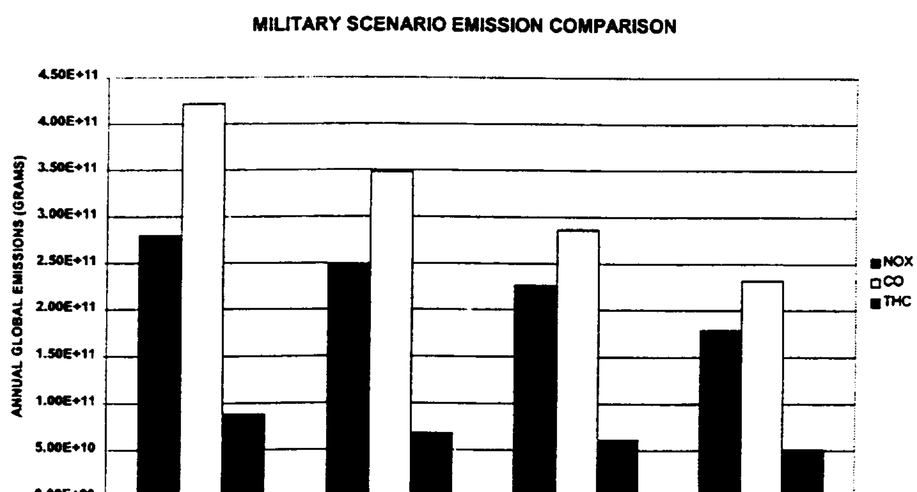


Figure 18 Regional military inventory comparisons for each historic scenario year

As a consequence of a continuing decrease in both inventories and their sub-element structures a continuous decline in annual fuel use and emissions was projected for these scenario years. This decline, as shown in Figure 19, is manifested in a continuous decline in overall emissions for all scenario years considered.



	1976	1984	1992	2015
NOX	2.80E+11	2.48E+11	2.27E+11	1.79E+11
CO	4.22E+11	3.48E+11	2.86E+11	2.32E+11
THC	8.84E+10	6.77E+10	6.14E+10	5.10E+10

SCENARIO YEAR

Figure 19 Military emission comparisons by scenario year

Distributions of annual Military NO_X in the scenario years 1992 and 2015 are presented Figure 20, Figure 21, Figure 22 and Figure 23. Peak distributions occur in the northern latitudes and between 10 to 14 kilometers. As previously described, Military inventories and activities are predominantly located in the northern hemisphere. Although not depicted, both CO and THC have parallel distributions.

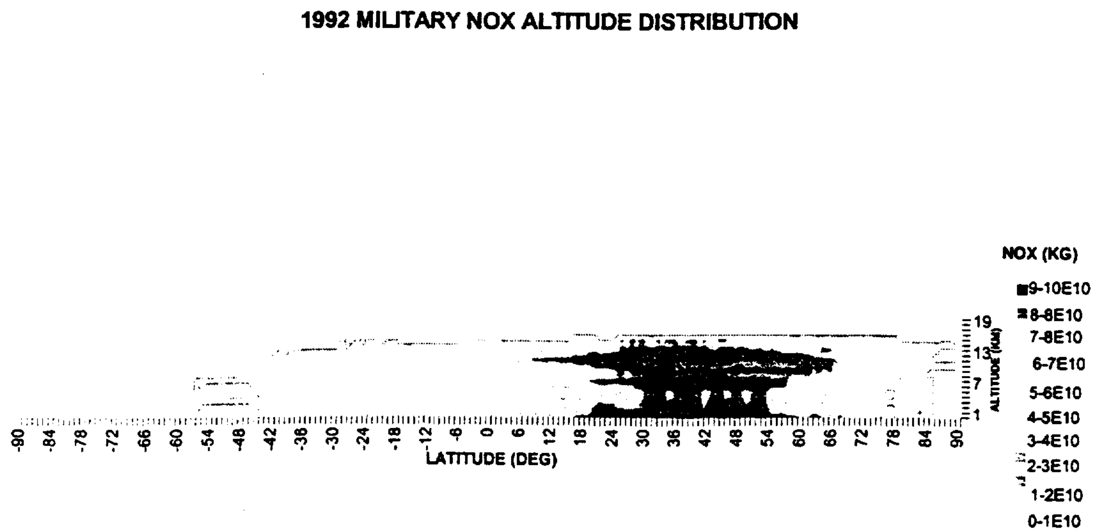


Figure 20 Altitude distribution of global military NO_X in the 1992 scenario

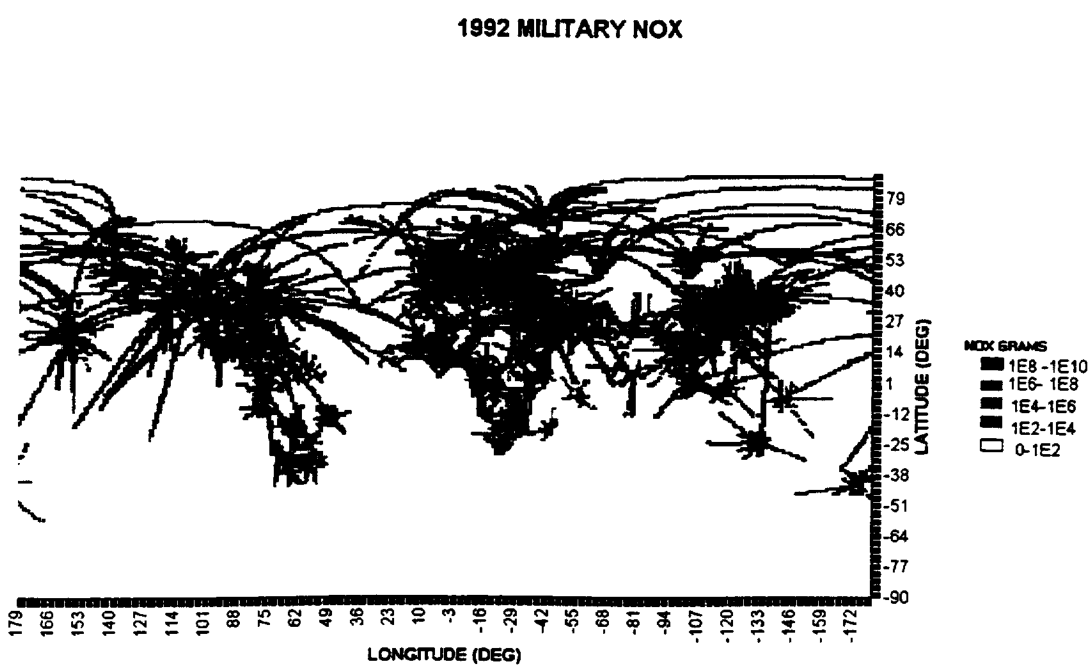


Figure 21 Geographic distribution of Military NO_X in the 1992 scenario

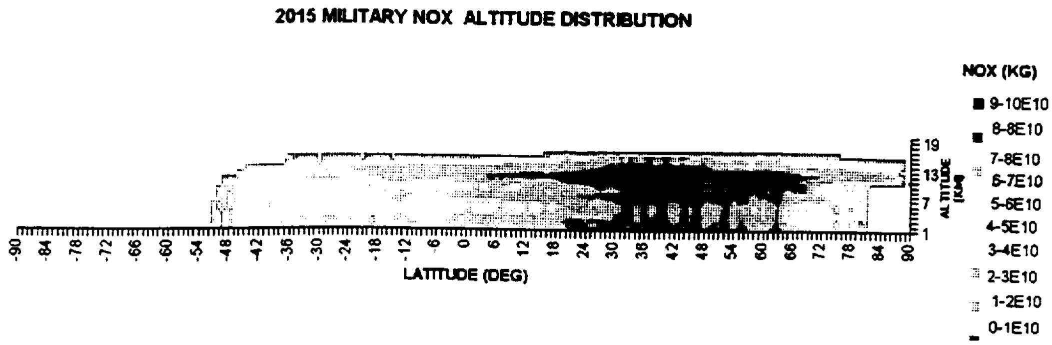


Figure 22 Altitude distribution of global military NO_X in the 2015 scenario

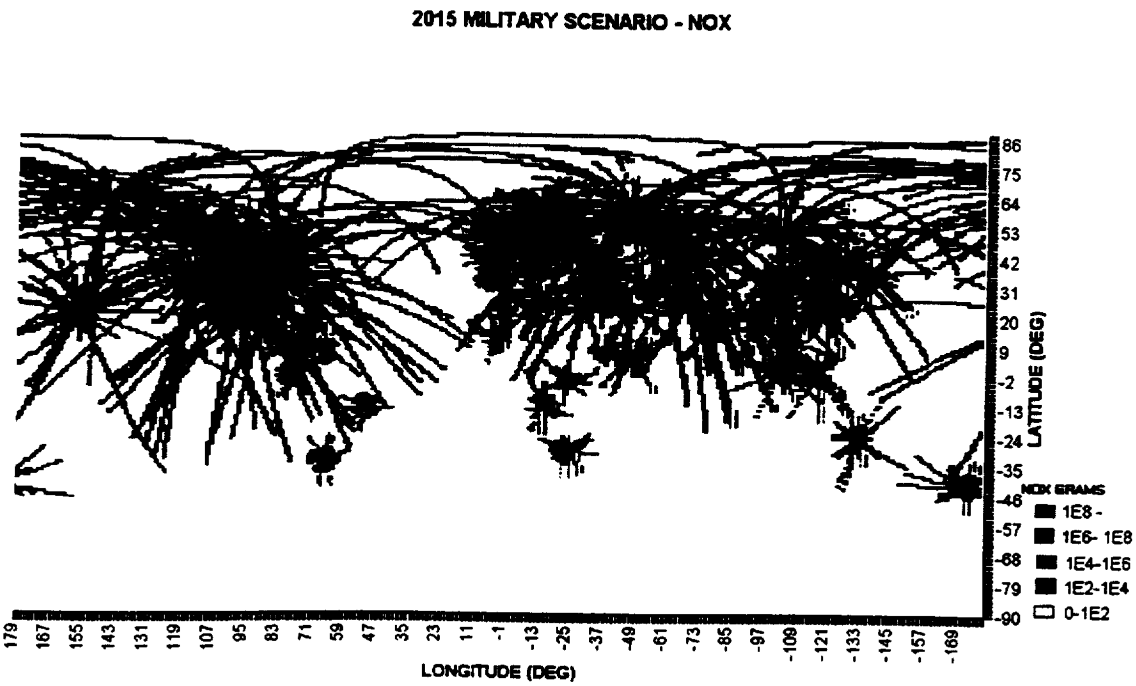


Figure 23 Geographic distribution of Military NO_X in the 2015 scenario

Summary results of the annual Military component database fuel burn and emission estimates by altitude band for the 2015, 1992, 1984 and 1976 scenario years are presented in Table 2 through Table 5 respectively. For comparison and a historical record only, similar tabular results of the initial delivered databases are provided in Appendix A.

Table 2 2015 Military Component Fuel Burn and Engine Exhaust Emission Estimates

	FUEL		NOX		CO		THC		Emission Index (EI)		
Alt. Band (KM)	Kilograms ($x10^9$)	Cum. Fuel	Grams ($x10^9$)	Cum. NOX	Grams ($x10^9$)	Cum. CO	Grams ($x10^9$)	Cum. THC	NOX	CO	THC
1	2.29	11.1%	23.35	13.0%	25.38	10.9%	3.73	7.3%	10.2	11.1	1.6
2	1.35	17.7%	10.08	18.7%	16.39	18.0%	1.95	11.1%	7.5	12.1	1.4
3	0.69	21.0%	6.39	22.2%	5.33	20.3%	2.00	15.0%	9.3	7.8	2.9
4	0.53	23.6%	4.73	24.9%	4.20	22.1%	1.49	18.0%	8.9	7.9	2.8
5	0.35	25.3%	3.53	26.9%	3.47	23.6%	1.36	20.6%	10.2	10.0	3.9
6	0.34	26.9%	3.51	28.8%	3.44	25.1%	1.35	23.3%	10.2	10.0	3.9
7	1.14	32.5%	6.76	32.6%	11.73	30.2%	7.63	38.2%	5.9	10.3	6.7
8	1.53	39.9%	11.04	38.8%	21.64	39.5%	1.68	41.5%	7.2	14.2	1.1
9	0.92	44.4%	10.54	44.6%	8.66	43.2%	1.71	44.9%	11.4	9.4	1.9
10	2.11	54.6%	26.71	59.6%	21.22	52.4%	4.09	52.9%	12.7	10.1	1.9
11	3.06	69.5%	22.04	71.9%	37.94	68.7%	7.29	67.2%	7.2	12.4	2.4
12	3.18	85.0%	21.66	84.0%	35.33	84.0%	7.81	82.5%	6.8	11.1	2.5
13	2.10	95.1%	16.46	93.2%	25.85	95.1%	5.34	92.9%	7.9	12.3	2.6
14	0.62	98.1%	8.10	97.7%	6.29	97.8%	1.86	96.6%	13.1	10.2	3.0
15	0.22	99.2%	1.85	98.7%	3.45	99.3%	1.35	99.2%	8.5	16.0	6.3
16	0.17	100.0%	2.28	100.0%	1.55	100.0%	0.39	100.0%	13.8	9.4	2.3
Total	20.58		179.02		231.87		51.02				

Table 3 1992 Military Scenario Component Fuel Burn and Engine Exhaust Emission Estimates

Alt. Band (KM)	FUEL Kilograms ($x10^9$)	Cum. Fuel	NOX Grams ($x10^9$)	Cum. NOX	CO Grams ($x10^9$)	Cum. CO	THC Grams ($x10^9$)	Cum. THC	Emission Index (EI) NOX	CO	THC
1	3.30	13.0%	35.97	15.9%	33.50	11.7%	4.51	7.4%	10.9	10.2	1.4
2	1.56	19.1%	11.93	21.1%	18.60	18.2%	2.28	11.1%	7.6	11.9	1.5
3	0.81	22.3%	7.69	24.5%	6.31	20.4%	2.31	14.8%	9.4	7.7	2.8
4	0.66	24.9%	6.01	27.2%	5.16	22.2%	1.77	17.7%	9.1	7.8	2.7
5	0.45	26.7%	4.62	29.2%	4.32	23.7%	1.63	20.4%	10.3	9.6	3.6
6	0.45	28.4%	4.62	31.3%	4.30	25.2%	1.62	23.0%	10.3	9.6	3.6
7	1.48	34.2%	9.16	35.3%	15.08	30.5%	9.22	38.0%	6.2	10.2	6.2
8	1.85	41.5%	13.72	41.3%	24.79	39.2%	1.96	41.2%	7.4	13.4	1.1
9	0.99	45.4%	10.46	46.0%	9.52	42.5%	1.97	44.5%	10.6	9.6	2.0
10	2.76	56.2%	34.80	61.3%	27.71	52.2%	5.37	53.2%	12.6	10.0	1.9
11	3.84	71.3%	27.47	73.4%	49.61	69.6%	9.18	68.2%	7.2	12.9	2.4
12	3.47	84.9%	23.66	83.9%	39.52	83.4%	8.25	81.6%	6.8	11.4	2.4
13	2.41	94.4%	19.32	92.4%	31.16	94.3%	6.00	91.4%	8.0	12.9	2.5
14	0.86	97.8%	11.00	97.3%	8.96	97.4%	2.71	95.8%	12.9	10.5	3.2
15	0.33	99.0%	2.86	98.5%	5.15	99.2%	2.00	99.1%	8.8	15.7	6.1
16	0.24	100.0%	3.36	100.0%	2.28	100.0%	0.57	100.0%	13.8	9.4	2.3
Total	**25.47**		**226.64**		**285.96**		**61.36**				

Table 4 1984 Military Scenario Component Fuel Burn and engine Exhaust Emission Estimates

Alt. Band (KM)	FUEL Kilograms (x10⁹)	FUEL Cum. Fuel	NOX Grams (x10⁹)	NOX Cum. NOX	CO Grams (x10⁹)	CO Cum. CO	THC Grams (x10⁹)	THC Cum. THC	Emission Index (EI) NOX	Emission Index (EI) CO	Emission Index (EI) THC
1	3.98	13.6%	40.33	16.2%	43.65	12.5%	5.60	8.3%	10.1	11.0	1.4
2	2.12	20.9%	15.57	22.5%	25.76	20.0%	2.71	12.3%	7.3	12.1	1.3
3	0.91	24.0%	8.47	25.9%	7.42	22.1%	2.64	16.2%	9.3	8.1	2.9
4	0.90	27.0%	7.55	29.0%	6.71	24.0%	2.11	19.3%	8.4	7.5	2.4
5	0.53	28.9%	5.23	31.1%	5.33	25.5%	1.91	22.1%	9.9	10.0	3.6
6	0.53	30.7%	5.23	33.2%	5.33	27.1%	1.91	24.9%	9.9	10.0	3.6
7	1.68	36.4%	9.63	37.1%	18.33	32.3%	11.46	41.8%	5.7	10.9	6.8
8	2.24	44.1%	16.19	43.6%	32.80	41.8%	2.31	45.2%	7.2	14.6	1.0
9	0.67	46.4%	6.11	46.0%	6.49	43.6%	1.36	47.2%	9.1	9.7	2.0
10	3.49	58.3%	44.97	64.2%	35.86	53.9%	6.55	56.9%	12.9	10.3	1.9
11	4.46	73.6%	29.97	76.2%	62.72	72.0%	9.93	71.6%	6.7	14.1	2.2
12	3.92	87.0%	26.04	86.7%	47.31	85.6%	8.86	84.7%	6.7	12.1	2.3
13	2.79	96.5%	20.88	95.1%	38.22	96.6%	6.48	94.2%	7.5	13.7	2.3
14	0.64	98.7%	8.28	98.5%	6.77	98.5%	2.02	97.2%	12.9	10.5	3.1
15	0.21	99.4%	1.53	99.1%	3.60	99.5%	1.47	99.4%	7.4	17.4	7.1
16	0.17	100.0%	2.29	100.0%	1.61	100.0%	0.42	100.0%	13.6	9.6	2.5
Total	**29.25**		**248.27**		**347.92**		**67.72**				

Table 5 1976 Military Component Scenario Fuel Burn and Engine Exhaust Emission Estimates

Alt. Band	FUEL		NOX		CO		THC		Emission Index (EI)		
(KM)	Kilograms ($x10^9$)	Cum. Fuel	Grams ($x10^9$)	Cum. NOX	Grams ($x10^9$)	Cum. CO	Grams ($x10^9$)	Cum. THC	NOX	CO	THC
1	4.75	13.6%	44.01	15.7%	55.64	13.2%	8.18	9.2%	10.9	10.2	1.4
2	3.35	23.1%	23.48	24.1%	41.15	23.0%	4.56	14.4%	7.6	11.9	1.5
3	1.41	27.1%	12.11	28.4%	11.76	25.7%	4.44	19.4%	9.4	7.7	2.8
4	1.42	31.2%	10.88	32.3%	10.76	28.3%	3.61	23.5%	9.1	7.8	2.7
5	0.81	33.5%	6.99	34.8%	8.44	30.3%	3.28	27.2%	10.3	9.6	3.6
6	0.81	35.8%	6.99	37.3%	8.43	32.3%	3.27	30.9%	10.3	9.6	3.6
7	2.63	43.3%	12.83	41.9%	32.66	40.0%	20.46	54.1%	6.2	10.2	6.2
8	3.29	52.7%	22.59	49.9%	52.37	52.5%	3.59	58.1%	7.4	13.4	1.1
9	0.78	54.9%	6.75	52.3%	7.87	54.3%	1.73	60.1%	10.6	9.6	2.0
10	3.13	63.9%	39.56	66.5%	32.22	62.0%	5.97	66.8%	12.6	10.0	1.9
11	4.55	76.9%	31.26	77.6%	59.18	76.0%	10.26	78.4%	7.2	12.9	2.4
12	4.27	89.0%	28.38	87.7%	53.33	88.7%	9.36	89.0%	6.8	11.4	2.4
13	2.88	97.2%	22.14	95.6%	37.39	97.5%	6.59	96.5%	8.0	12.9	2.5
14	0.62	99.0%	8.37	98.6%	6.01	99.0%	1.63	98.3%	12.9	10.5	3.2
15	0.17	99.5%	1.38	99.1%	2.86	99.6%	1.14	99.6%	8.8	15.7	6.1
16	0.17	100.0%	2.44	100.0%	1.51	100.0%	0.35	100.0%	13.8	9.4	2.3
Total	**35.06**		**280.16**		**421.58**		**88.43**				

5.2 CHARTER AND UNREPORTED DOMESTIC TRAFFIC COMPONENT SCENARIO RESULTS

Both the Charter and Unreported Domestic Traffic component fuel burn and emissions are directly effected by passenger volume demands on the air traffic network. Details of the development of the component 1992 and 2015 air traffic models have previously been provided (Ward, Reference 1,1994 and Metwally, Reference 2, 1995). The Charter component models for 1984 and 1976 scenarios were updated to reflect introduction of both additional city pairs and generic aircraft types. As shown in Figure 24, Charter model was reported to have 192 billion revenue passenger kilometers (RPK) in 1984 and 194 billion RPK in 1976. This compares to the 186 billion RPK in 1992 and the projected 392 billion RPK in 2015 that have been previously reported.

The network model for Unreported Domestic Traffic was unchanged from that employed for the 1992 and 2015 estimates. The network was loaded with a passenger demand load demands supporting 207 billion Available Seat Kilometers (ASK) in 1984 and 168 ASK in 1976. This passenger demand was apportioned among the 269 routes within the initial network based on flight frequency and geographic distribution. The final network model containing 91 routes is a subset of the top service frequency, with the traffic re-distributed among them. As shown in Figure 25 the passenger demand loads have shown continued growth through each of the scenario years.

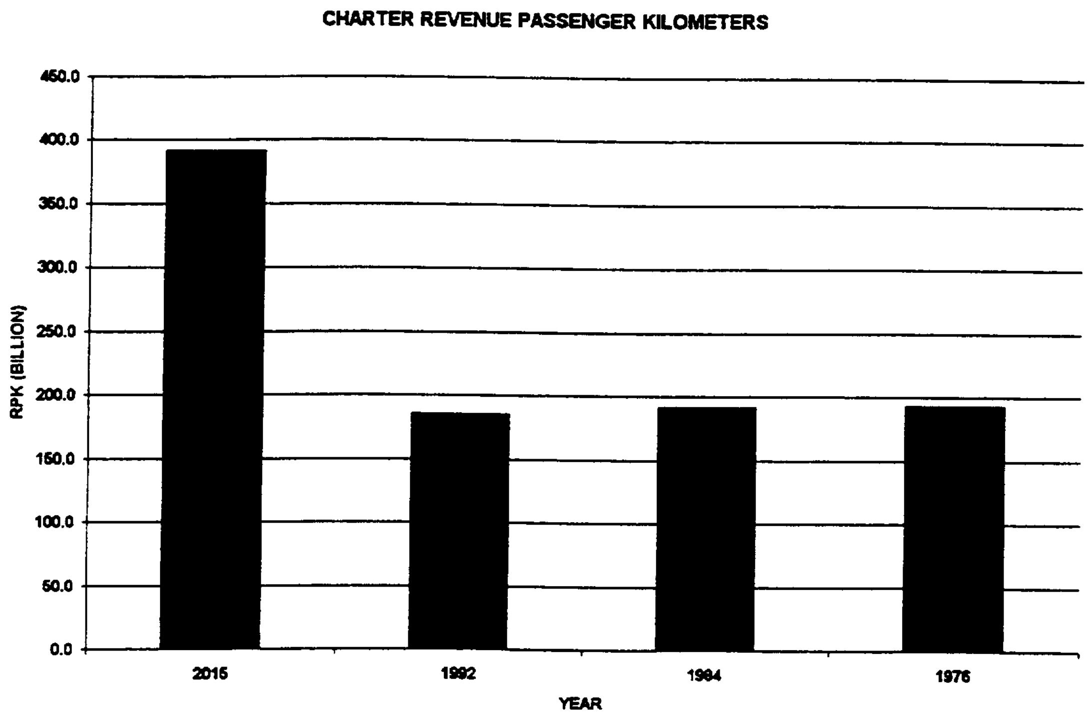


Figure 24 Charter component network demand for each scenario year

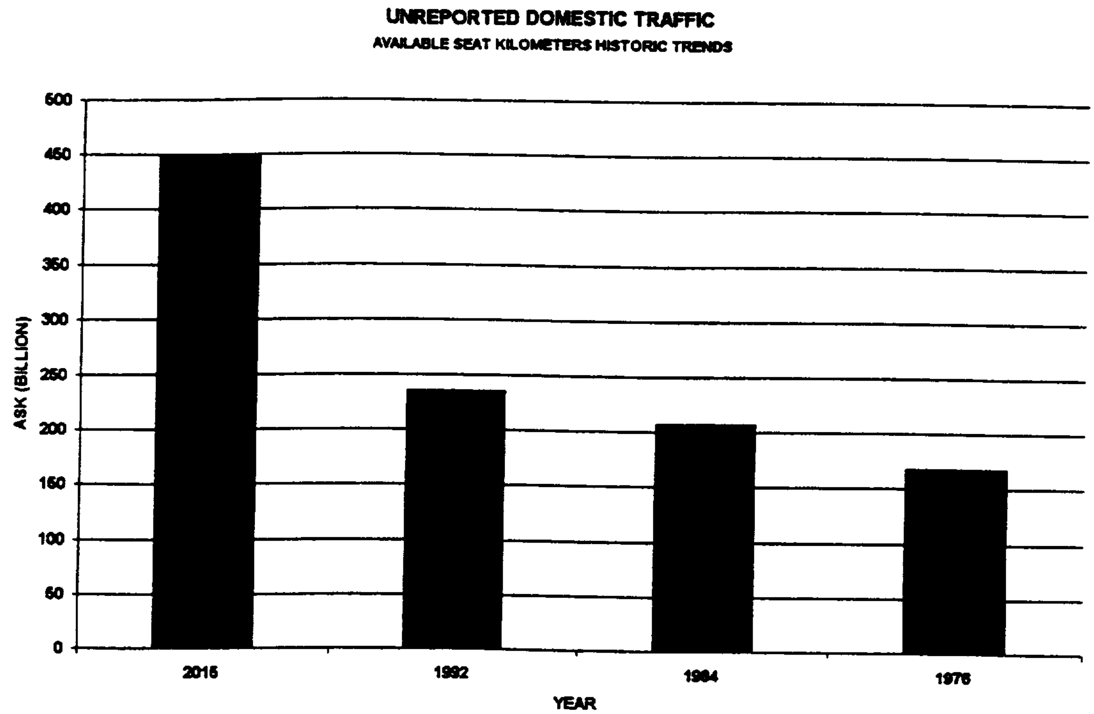
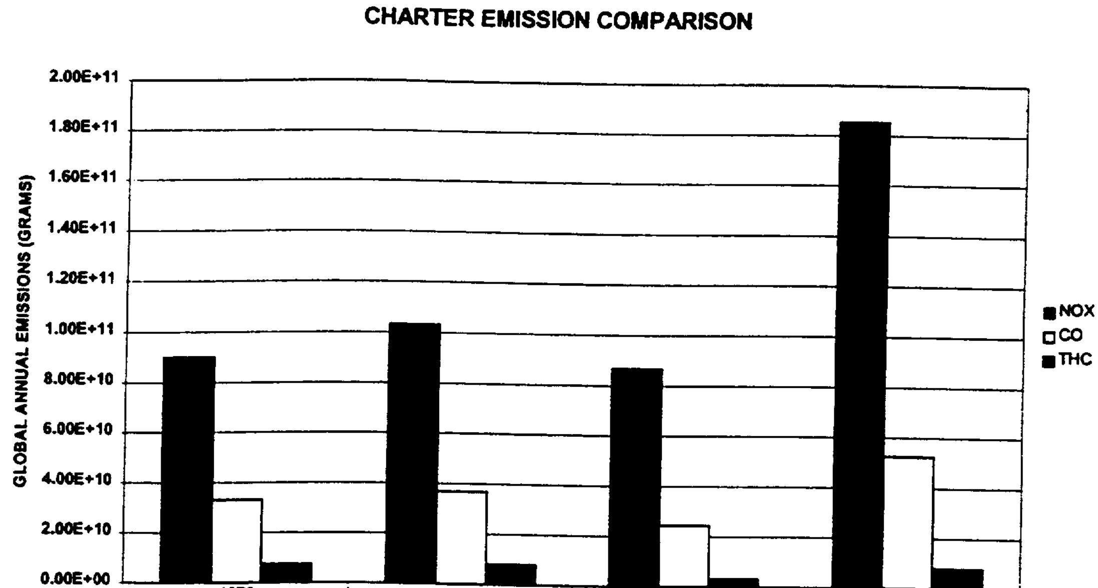


Figure 25 Unreported domestic traffic network demand for each scenario year

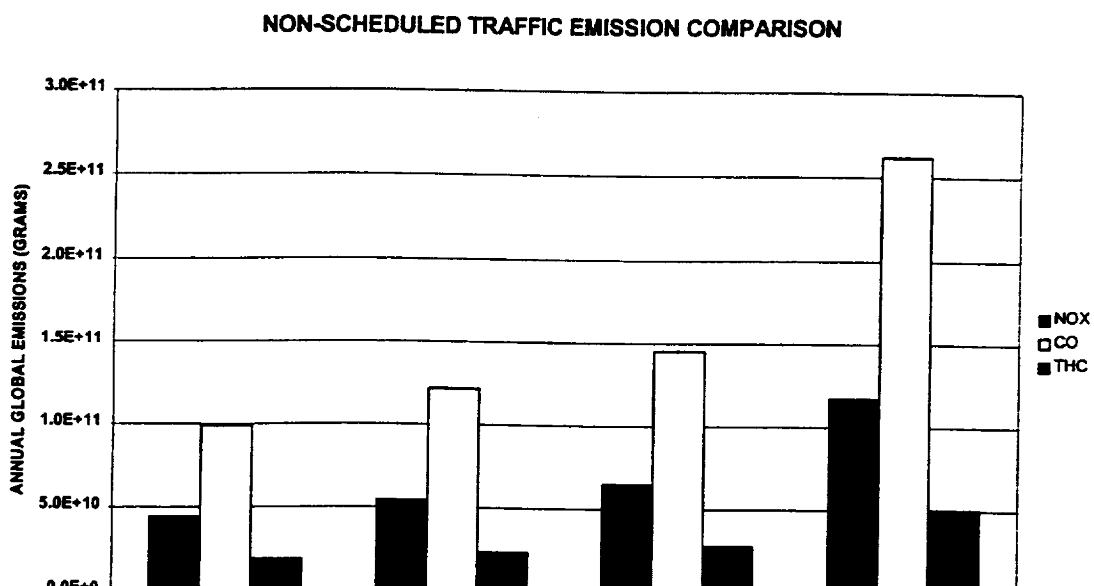
As a consequence of the relatively moderate changes in overall Charter growth patterns, the Charter emissions have remained constant between 1976 and 1984 compared to other aviation components. During this period, as shown in Figure 26, the component produced nearly 90 million annual kilograms of NO_X, and 30 million annual kilograms of CO. These values are predicted to double by 2015 from the increased passenger load demands predicted for the component. A similar emission growth pattern as shown in Figure 27 is evident for the Unreported Domestic component emissions. Emissions within this component are reflective of the system ASK increasing from 44 million kilograms of NO_X in 1976 to 65 million kilograms in 1992. Although forecasts of near term growth patterns within the former CIS are uncertain, it is believed overall growth by 2015 will exhibit projections of historic year performance. As a result, 117 million kilograms of NO_X, and 262 million kilograms of CO are forecast.



	1976	1984	1992	2015
NOX	9.01E+10	1.03E+11	8.68E+10	1.85E+11
CO	3.32E+10	3.69E+10	2.45E+10	5.26E+10
THC	7.47E+09	8.08E+09	3.29E+09	8.00E+09

SCENARIO YEAR

Figure 26 Charter emission comparisons by scenario year



	1976	1984	1992	2015
NOX	4.40E+10	5.41E+10	6.47E+10	1.17E+11
CO	9.88E+10	1.21E+11	1.45E+11	2.62E+11
THC	1.91E+10	2.34E+10	2.80E+10	5.05E+10

SCENARIO YEAR

Figure 27 Unreported domestic traffic emission comparisons by scenario year

Distributions of annual Charter NO_X in the scenario years 1992 and 2015 are presented in Figure 28, Figure 29, Figure 30, and Figure 31. Peak distributions occur in the northern latitudes, especially across the north Atlantic, between 9 to 11 kilometers. Although not shown, both CO and THC have similar distributions.

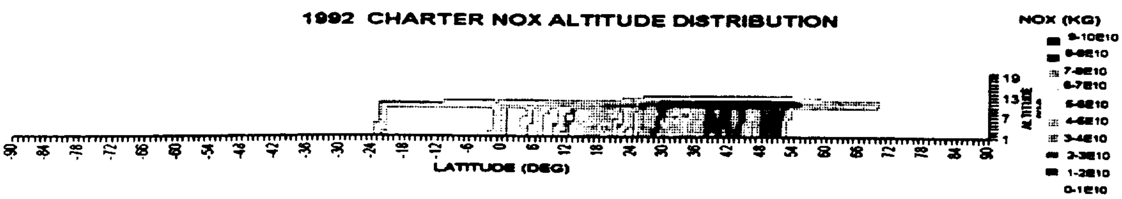


Figure 28 Altitude distribution of Charter component NO_X in the 1992 scenario

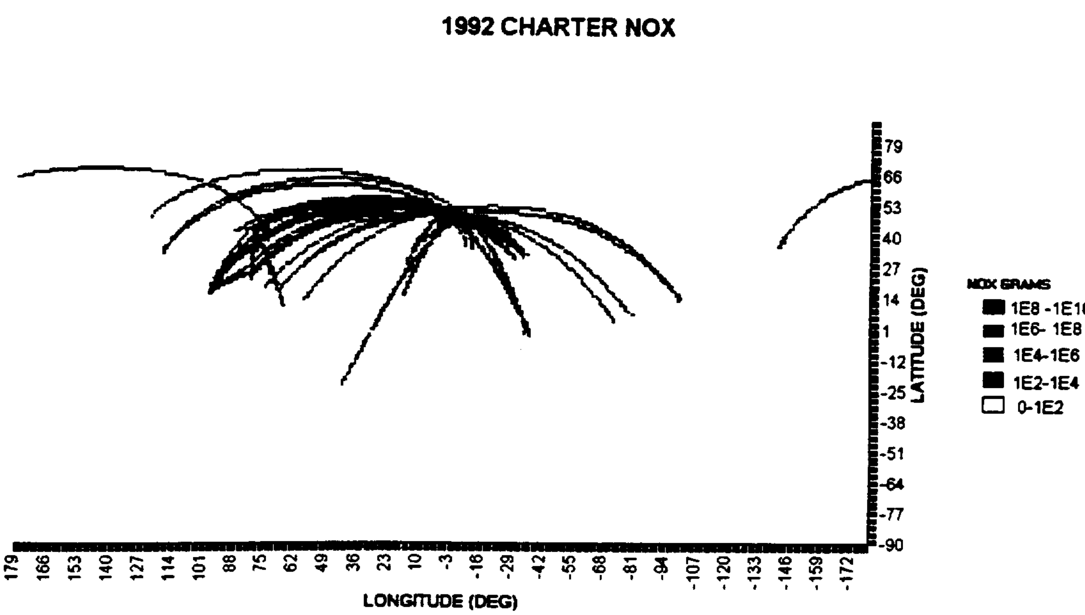


Figure 29 Geographic distribution of Charter component NO_X in the 1992 scenario

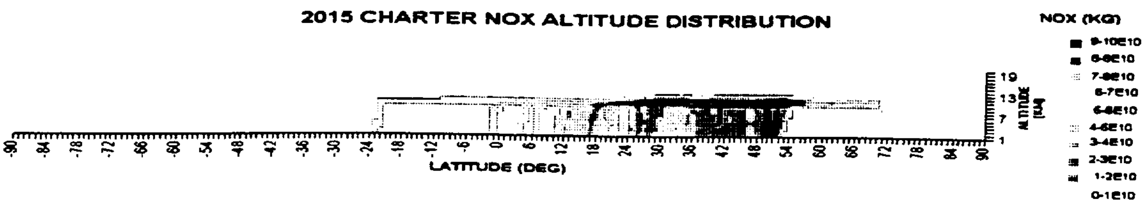


Figure 30 Altitude distribution of Charter component NO_X in the 2015 scenario

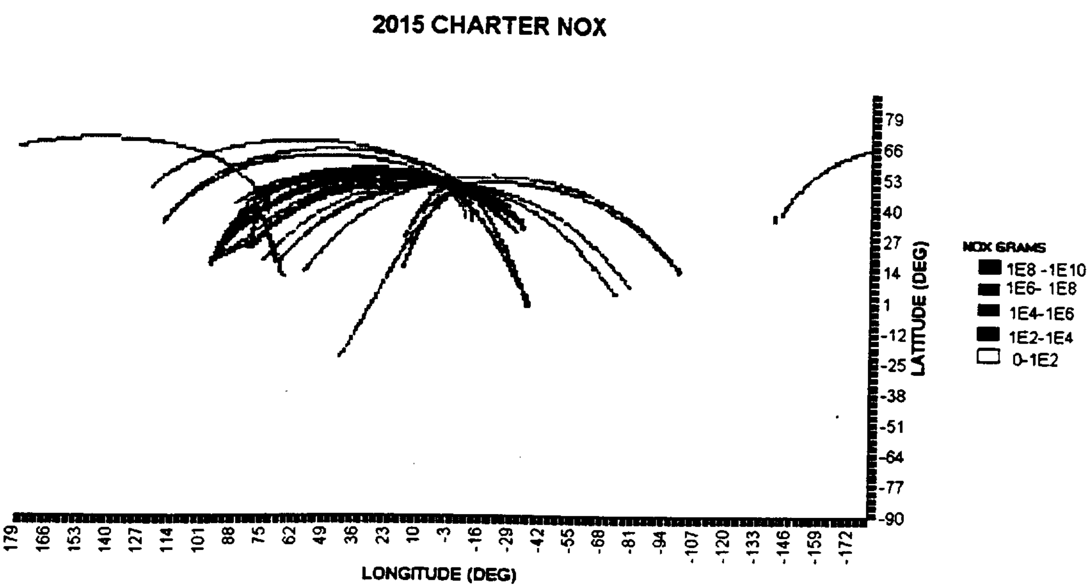


Figure 31 Geographic distribution of Charter component NO_X in the 2015 scenario

Emission distributions of annual Unreported Domestic NO_X in the scenario years 1992 and 2015 are presented in Figure 32, Figure 33, Figure 34, and Figure 35. These distributions are restricted to within the regions of the former CIS, China and Warsaw pact countries. Peak altitude distributions occur between 10 to 12 kilometers. Although not shown, both CO and THC have similar distributions.

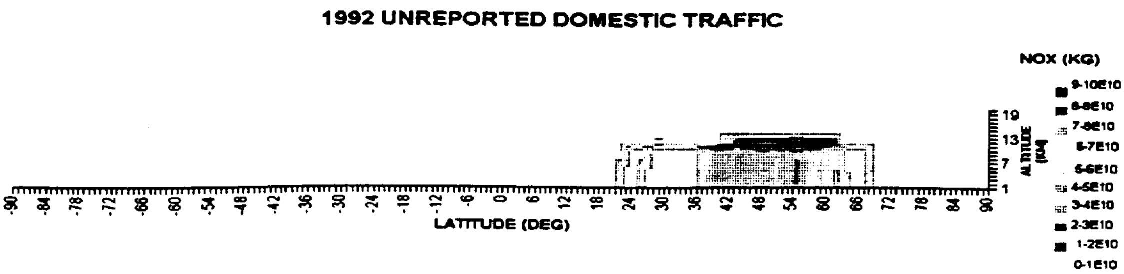


Figure 32 Altitude distribution of the Unreported Domestic component NO_X in the 1992 scenario

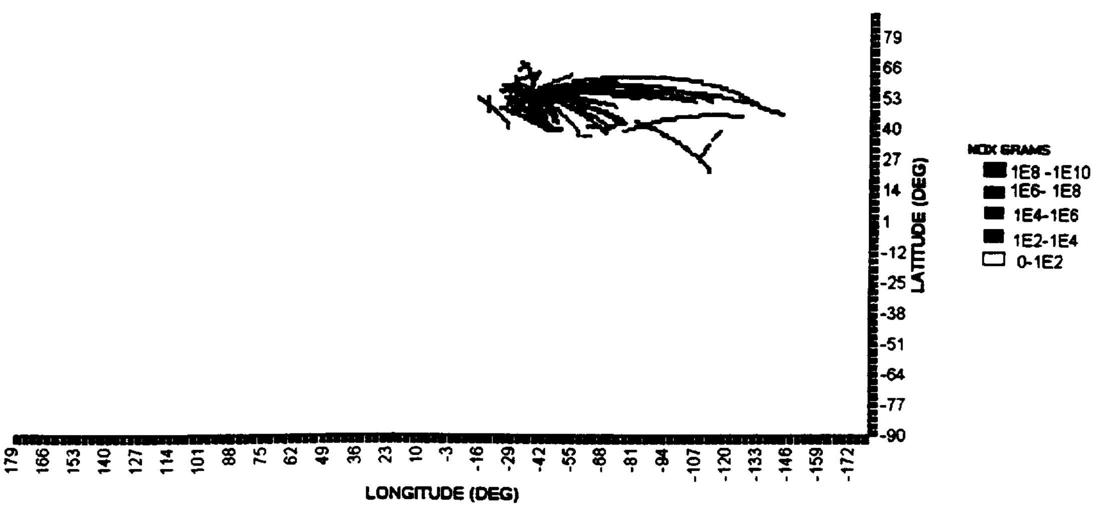


Figure 33 Geographic distribution of the Unreported Domestic component NO_X in the 1992 scenario

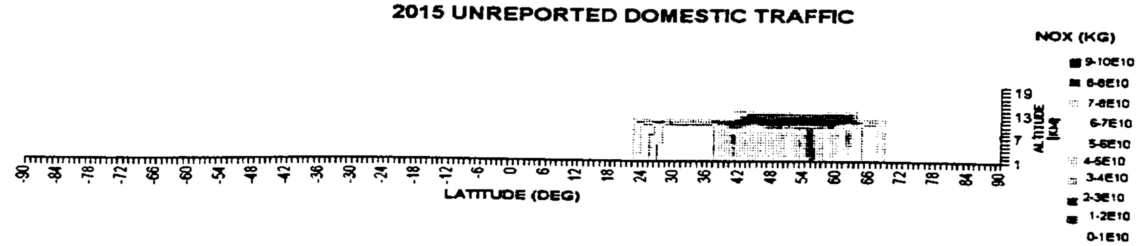


Figure 34 Altitude distribution of the Unreported Domestic component NO_X in the 2015 scenario

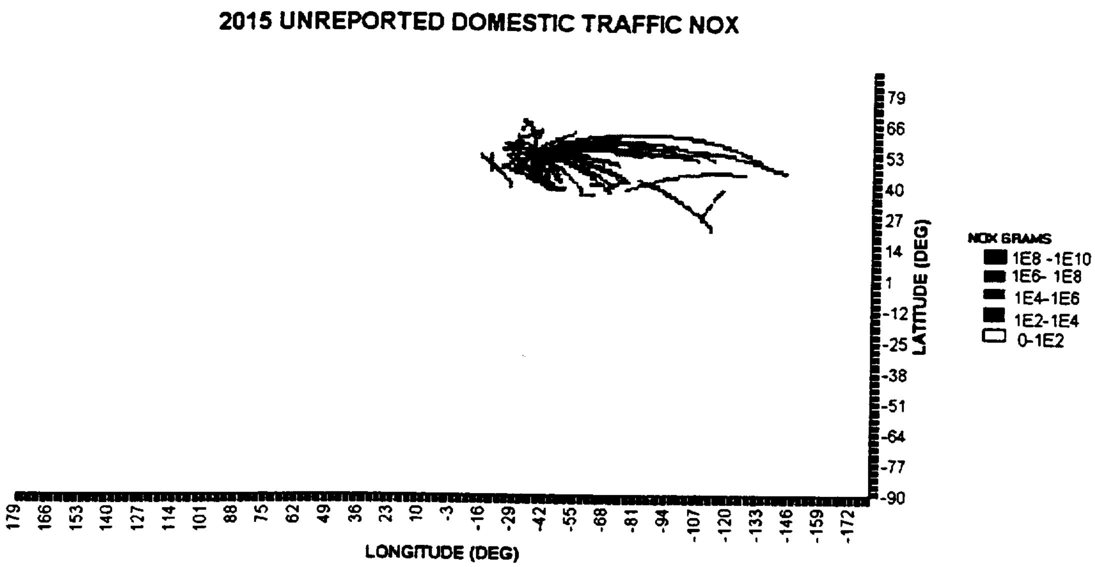


Figure 35 Geographic distribution of the Unreported Domestic component NO_X in the 2015 scenario

Summary results of the Charter component database fuel burn and emission estimates by altitude band for the four scenario years are presented in Table 6 through Table 9. Similarly, Table 10 through Table 13 provide summary results for the Unreported Domestic component. For comparison and a historical record only, similar tabular results of the initially delivered databases are provided in Appendix A.

Table 6 2015 Charter Component Scenario Fuel Burn and Egine Exhaust Emission Estimates

Alt. Band (KM)	FUEL Kilograms ($x10^9$)	Cum. Fuel	NOX Grams ($x10^9$)	Cum. NOX	CO Grams ($x10^9$)	Cum. CO	THC Grams ($x10^9$)	Cum. THC	Emission Index (EI) NOX	CO	THC
1	0.62	4.6%	8.31	4.5%	7.91	15.0%	1.51	18.9%	13.3	12.67	2.42
2	0.62	9.3%	11.46	10.7%	2.45	19.7%	0.43	24.2%	18.35	3.93	0.68
3	0.62	13.9%	11.45	16.8%	2.45	24.4%	0.43	29.6%	18.35	3.93	0.69
4	0.62	18.5%	11.44	23.0%	2.45	29.0%	0.43	34.9%	18.36	3.93	0.69
5	0.69	23.7%	12.00	29.5%	2.66	34.1%	0.43	40.2%	17.27	3.82	0.61
6	0.59	28.0%	10.90	35.4%	2.30	38.4%	0.42	45.5%	18.49	3.89	0.71
7	0.59	32.4%	10.89	41.2%	2.29	42.8%	0.42	50.7%	18.5	3.89	0.71
8	0.59	36.7%	10.85	47.1%	2.28	47.1%	0.42	55.9%	18.51	3.89	0.71
9	0.58	41.1%	10.82	52.9%	2.27	51.4%	0.42	61.1%	18.53	3.89	0.71
10	4.20	72.2%	43.46	76.3%	13.92	77.9%	1.18	75.8%	10.34	3.31	0.28
11	2.90	93.7%	33.91	94.6%	9.01	95.0%	1.49	94.5%	11.7	3.11	0.52
12	0.85	100.0%	9.95	100.0%	2.64	100.0%	0.44	100.0%	11.7	3.11	0.52
Total	13.49		185.45		52.64		8.00				

Table 7 1992 Charter Component Scenario Fuel Burn and Engine Emission Estimates

Alt. Band (KM)	FUEL Kilograms ($x10^9$)	FUEL Cum. Fuel	NOX Grams ($x10^9$)	NOX Cum. NOX	CO Grams ($x10^9$)	CO Cum. CO	THC Grams ($x10^9$)	THC Cum. THC	Emission Index (EI) NOX	Emission Index (EI) CO	Emission Index (EI) THC
1	0.29	4.5%	3.63	4.2%	3.54	14.5%	0.58	17.5%	12.5	12.2	2.0
2	0.29	8.9%	5.05	10.0%	1.13	19.1%	0.16	22.4%	17.3	3.9	0.6
3	0.29	13.4%	5.05	15.8%	1.13	23.7%	0.16	27.2%	17.3	3.9	0.6
4	0.29	17.8%	5.06	21.6%	1.13	28.3%	0.16	32.1%	17.3	3.9	0.6
5	0.32	22.7%	5.27	27.7%	1.21	33.2%	0.16	37.0%	16.5	3.8	0.5
6	0.28	26.9%	4.81	33.3%	1.06	37.6%	0.16	41.8%	17.4	3.8	0.6
7	0.28	31.1%	4.81	38.8%	1.05	41.9%	0.16	46.5%	17.4	3.8	0.6
8	0.27	35.3%	4.79	44.3%	1.05	46.2%	0.16	51.3%	17.4	3.8	0.6
9	0.27	39.5%	4.77	49.8%	1.04	50.4%	0.16	56.0%	17.5	3.8	0.6
10	2.10	71.6%	21.75	74.8%	6.75	78.0%	0.55	72.7%	10.4	3.2	0.3
11	1.44	93.6%	16.89	94.3%	4.15	95.0%	0.70	93.8%	11.7	2.9	0.5
12	0.42	100.0%	4.95	100.0%	1.22	100.0%	0.20	100.0%	11.7	2.9	0.5
Total	**6.55**		**86.84**		**24.45**		**3.29**				

Table 8 1984 Charter Component Scenario Fuel Burn and Engine Exhaust Emission Estimates

Alt. Band (KM)	FUEL Kilograms ($x10^9$)	FUEL Cum. Fuel	NOX Grams ($x10^9$)	NOX Cum. NOX	CO Grams ($x10^9$)	CO Cum. CO	THC Grams ($x10^9$)	THC Cum. THC	Emission Index (EI) NOX	Emission Index (EI) CO	Emission Index (EI) THC
1	0.38	4.1%	4.36	4.2%	4.50	12.2%	1.40	17.3%	11.6	12.0	3.7
2	0.30	7.4%	4.70	8.8%	1.42	16.1%	0.41	22.4%	15.5	4.7	1.4
3	0.28	10.4%	4.42	13.1%	1.00	18.8%	0.26	25.6%	15.9	3.6	0.9
4	0.28	13.5%	4.46	17.4%	1.01	21.5%	0.26	28.8%	15.9	3.6	0.9
5	0.28	16.5%	4.47	21.7%	1.01	24.2%	0.26	32.0%	15.9	3.6	0.9
6	0.28	19.6%	4.46	26.0%	1.00	26.9%	0.26	35.2%	15.9	3.6	0.9
7	0.31	23.0%	4.78	30.7%	1.07	29.9%	0.33	39.3%	15.3	3.4	1.1
8	0.42	27.6%	6.18	36.6%	1.60	34.2%	0.36	43.7%	14.6	3.8	0.8
9	0.24	30.2%	3.94	40.5%	0.76	36.2%	0.17	45.9%	16.8	3.2	0.7
10	0.70	37.8%	6.74	47.0%	2.44	42.9%	0.23	48.7%	9.7	3.5	0.3
11	3.80	79.2%	33.15	79.1%	12.29	76.2%	2.32	77.4%	8.7	3.2	0.6
12	1.91	100.0%	21.58	100.0%	8.78	100.0%	1.83	100.0%	11.3	4.6	1.0
Total	**9.18**		**103.24**		**36.86**		**8.08**				

Table 9 1976 Charter Component Scenario Fuel Burn and Engine Exhaust Emission Estimates

Alt. Band (KM)	FUEL Kilograms ($x10^9$)	FUEL Cum. Fuel	NOX Grams ($x10^9$)	NOX Cum. NOX	CO Grams ($x10^9$)	CO Cum. CO	THC Grams ($x10^9$)	THC Cum. THC	Emission Index (EI) NOX	Emission Index (EI) CO	Emission Index (EI) THC
1	0.35	4.2%	3.61	4.0%	4.06	12.2%	1.71	22.9%	10.4	11.7	4.9
2	0.32	8.1%	4.51	9.0%	1.53	16.8%	0.45	28.9%	13.9	4.7	1.4
3	0.32	12.0%	4.60	14.1%	1.15	20.3%	0.26	32.3%	14.2	3.6	0.8
4	0.32	15.9%	4.61	19.2%	1.14	23.8%	0.25	35.7%	14.2	3.5	0.8
5	0.32	19.8%	4.62	24.4%	1.15	27.2%	0.25	39.1%	14.2	3.5	0.8
6	0.32	23.7%	4.61	29.5%	1.14	30.7%	0.25	42.5%	14.2	3.5	0.8
7	0.34	27.8%	4.79	34.8%	1.17	34.2%	0.29	46.5%	14.0	3.4	0.9
8	0.51	33.9%	6.79	42.3%	1.96	40.1%	0.41	51.9%	13.2	3.8	0.8
9	0.28	37.3%	4.08	46.8%	0.89	42.8%	0.17	54.2%	14.6	3.2	0.6
10	0.79	46.7%	7.22	54.9%	2.76	51.1%	0.25	57.6%	9.2	3.5	0.3
11	3.21	85.2%	27.09	84.9%	10.33	82.2%	1.89	82.9%	8.4	3.2	0.6
12	1.23	100.0%	13.60	100.0%	5.90	100.0%	1.28	100.0%	11.1	4.8	1.0
Total	**8.33**		**90.13**		**33.19**		**7.47**				

Table 10 2015 Unreported Domestic Traffic Component Scenario Fuel Burn and Engine Exhaust Emission Estimates

Alt. Band (KM)	FUEL Kilograms ($x10^9$)	FUEL Cum. Fuel	NOX Grams ($x10^9$)	NOX Cum. NOX	CO Grams ($x10^9$)	CO Cum. CO	THC Grams ($x10^9$)	THC Cum. THC	Emission Index (EI) NOX	Emission Index (EI) CO	Emission Index (EI) THC
1	0.15	1.0%	0.57	0.5%	9.77	3.7%	7.19	14.2%	3.7	63.6	46.8
2	0.15	1.9%	1.33	1.6%	1.97	4.5%	0.33	14.9%	8.7	12.8	2.2
3	0.15	2.9%	1.33	2.8%	1.96	5.2%	0.33	15.5%	8.7	12.8	2.2
4	0.15	3.9%	1.32	3.9%	1.95	6.0%	0.33	16.2%	8.7	12.8	2.2
5	0.15	4.8%	1.32	5.0%	1.95	6.7%	0.33	16.8%	8.7	12.8	2.2
6	0.17	5.9%	1.51	6.3%	2.06	7.5%	0.35	17.5%	8.9	12.2	2.1
7	0.17	7.0%	1.48	7.6%	2.08	8.3%	0.35	18.2%	8.9	12.4	2.1
8	0.14	7.8%	1.15	8.6%	1.81	9.0%	0.30	18.8%	8.5	13.4	2.2
9	0.13	8.7%	1.14	9.5%	1.81	9.7%	0.30	19.4%	8.5	13.4	2.2
10	0.92	14.5%	5.26	14.0%	18.88	16.9%	3.35	26.0%	5.7	20.5	3.6
11	11.27	85.9%	74.59	77.8%	216.96	99.7%	34.51	94.4%	6.6	19.3	3.1
12	1.52	95.5%	17.73	92.9%	0.49	99.9%	1.93	98.2%	11.7	0.3	1.3
13	0.71	100.0%	8.28	100.0%	0.21	100.0%	0.90	100.0%	11.7	0.3	1.3
Total	15.79		117.02		261.89		50.50				

Table 11 1992 Unreported Domestic Traffic Component Scenario Fuel Burn and Engine Exhaust Emission Estimates

Alt. Band (KM)	FUEL Kilograms ($x10^9$)	FUEL Cum. Fuel	NOX Grams ($x10^9$)	NOX Cum. NOX	CO Grams ($x10^9$)	CO Cum. CO	THC Grams ($x10^9$)	THC Cum. THC	Emission Index (EI) NOX	Emission Index (EI) CO	Emission Index (EI) THC
1	0.09	1.0%	0.32	0.5%	5.42	3.7%	3.99	14.2%	3.7	63.6	46.9
2	0.09	1.9%	0.74	1.6%	1.09	4.5%	0.18	14.9%	8.7	12.8	2.2
3	0.08	2.9%	0.74	2.8%	1.09	5.2%	0.18	15.5%	8.7	12.8	2.2
4	0.08	3.9%	0.74	3.9%	1.09	6.0%	0.18	16.2%	8.7	12.8	2.2
5	0.08	4.9%	0.74	5.0%	1.09	6.7%	0.18	16.8%	8.7	12.8	2.2
6	0.08	5.8%	0.73	6.2%	1.08	7.5%	0.18	17.5%	8.7	12.8	2.2
7	0.09	6.9%	0.80	7.4%	1.14	8.3%	0.19	18.2%	8.8	12.5	2.1
8	0.08	7.7%	0.64	8.4%	1.01	9.0%	0.17	18.8%	8.5	13.4	2.2
9	0.07	8.6%	0.63	9.4%	1.01	9.6%	0.17	19.4%	8.5	13.4	2.2
10	0.51	14.5%	2.94	13.9%	10.54	16.9%	1.87	26.0%	5.7	20.5	3.6
11	6.24	85.8%	41.29	77.7%	120.23	99.6%	19.13	94.3%	6.6	19.3	3.1
12	0.85	95.5%	9.83	92.9%	0.41	99.9%	1.09	98.2%	11.6	0.5	1.3
13	0.39	100.0%	4.57	100.0%	0.12	100.0%	0.50	100.0%	11.7	0.3	1.3
Total	**8.74**		**64.72**		**145.31**		**28.02**				

Table 12 1984 Unreported Domestic Traffic Component Scenario Fuel Burn and Engine Exhaust Emission Estimates

Alt. Band	FUEL		NOX		CO		THC		Emission Index (EI)		
(KM)	Kilograms ($x10^9$)	Cum. Fuel	Grams ($x10^9$)	Cum. NOX	Grams ($x10^9$)	Cum. CO	Grams ($x10^9$)	Cum. THC	NOX	CO	THC
1	0.07	1.0%	0.27	0.5%	4.53	3.7%	3.33	14.2%	3.7	63.6	46.9
2	0.07	1.9%	0.62	1.6%	0.91	4.5%	0.15	14.9%	8.7	12.8	2.2
3	0.07	2.9%	0.62	2.8%	0.91	5.2%	0.15	15.5%	8.7	12.8	2.2
4	0.07	3.9%	0.62	3.9%	0.91	6.0%	0.15	16.2%	8.7	12.8	2.2
5	0.07	4.9%	0.61	5.0%	0.91	6.7%	0.15	16.8%	8.7	12.8	2.2
6	0.07	5.8%	0.61	6.2%	0.91	7.5%	0.15	17.5%	8.7	12.8	2.2
7	0.08	6.9%	0.67	7.4%	0.96	8.3%	0.16	18.2%	8.8	12.5	2.1
8	0.06	7.7%	0.53	8.4%	0.85	9.0%	0.14	18.8%	8.5	13.4	2.2
9	0.06	8.6%	0.53	9.4%	0.84	9.6%	0.14	19.4%	8.5	13.4	2.2
10	0.43	14.5%	2.46	13.9%	8.81	16.9%	1.56	26.0%	5.7	20.5	3.6
11	5.22	85.8%	34.51	77.7%	100.47	99.6%	15.99	94.3%	6.6	19.3	3.1
12	0.71	95.5%	8.22	92.9%	0.34	99.9%	0.91	98.2%	11.6	0.5	1.3
13	0.33	100.0%	3.82	100.0%	0.10	100.0%	0.42	100.0%	11.7	0.3	1.3
Total	7.31		54.08		121.44		23.42				

Table 13 1976 Unreported Domestic Traffic Component Scenario Fuel Burn and Engine Exhaust Emission Estimates

Alt. Band (KM)	FUEL Kilograms ($x10^9$)	FUEL Cum. Fuel	NOX Grams ($x10^9$)	NOX Cum. NOX	CO Grams ($x10^9$)	CO Cum. CO	THC Grams ($x10^9$)	THC Cum. THC	Emission Index (EI) NOX	Emission Index (EI) CO	Emission Index (EI) THC
1	0.06	1.0%	0.22	0.5%	3.68	3.7%	2.71	14.2%	3.7	63.6	46.9
2	0.06	1.9%	0.50	1.6%	0.74	4.5%	0.12	14.9%	8.7	12.8	2.2
3	0.06	2.9%	0.50	2.8%	0.74	5.2%	0.12	15.5%	8.7	12.8	2.2
4	0.06	3.9%	0.50	3.9%	0.74	6.0%	0.12	16.2%	8.7	12.8	2.2
5	0.06	4.9%	0.50	5.0%	0.74	6.7%	0.12	16.8%	8.7	12.8	2.2
6	0.06	5.8%	0.50	6.2%	0.74	7.5%	0.12	17.5%	8.7	12.8	2.2
7	0.06	6.9%	0.55	7.4%	0.78	8.3%	0.13	18.2%	8.8	12.5	2.1
8	0.05	7.7%	0.43	8.4%	0.69	9.0%	0.11	18.8%	8.5	13.4	2.2
9	0.05	8.6%	0.43	9.4%	0.68	9.6%	0.11	19.4%	8.5	13.4	2.2
10	0.35	14.5%	2.00	13.9%	7.17	16.9%	1.27	26.0%	5.7	20.5	3.6
11	4.24	85.8%	28.07	77.7%	81.75	99.6%	13.01	94.3%	6.6	19.3	3.1
12	0.58	95.5%	6.69	92.9%	0.28	99.9%	0.74	98.2%	11.6	0.5	1.3
13	0.27	100.0%	3.11	100.0%	0.08	100.0%	0.34	100.0%	11.7	0.3	1.3
Total	**5.95**		**44.00**		**98.81**		**19.05**				

5.3 GENERAL AVIATION RESULTS

The GA component is composed of four mission categories: executive jet, helicopter, turboprop, and piston. Unique mission categories exist within each aviation component. However the GA sub-components provide substantial individual contributions to the overall composition of its emission inventory. The executive jet, with its longer-range and high altitude mission profile provides both the geographic and altitude emission diversity. Helicopter operations, with both low altitude and short range provide relatively localized contributions. Representation of turboprop operations provides intermediate range and altitude emission contributions. Piston operations, besides restricted further than turboprops in both range and altitude, also have unique operational procedures impacting their emission characteristics.

Discussion of the GA component fuel burn and emissions must initially be focused on the geographic sources of operations. As previously shown in Table 1, North America and in particular the United States represents the largest source of GA inventory. This imbalance, as shown in Figure 36 through Figure 39, is manifested in the number of missions within regional areas. The North American region dominates each of the sub-component total missions. As a result additional bases were assigned within the region to better delineate its geographic distribution.

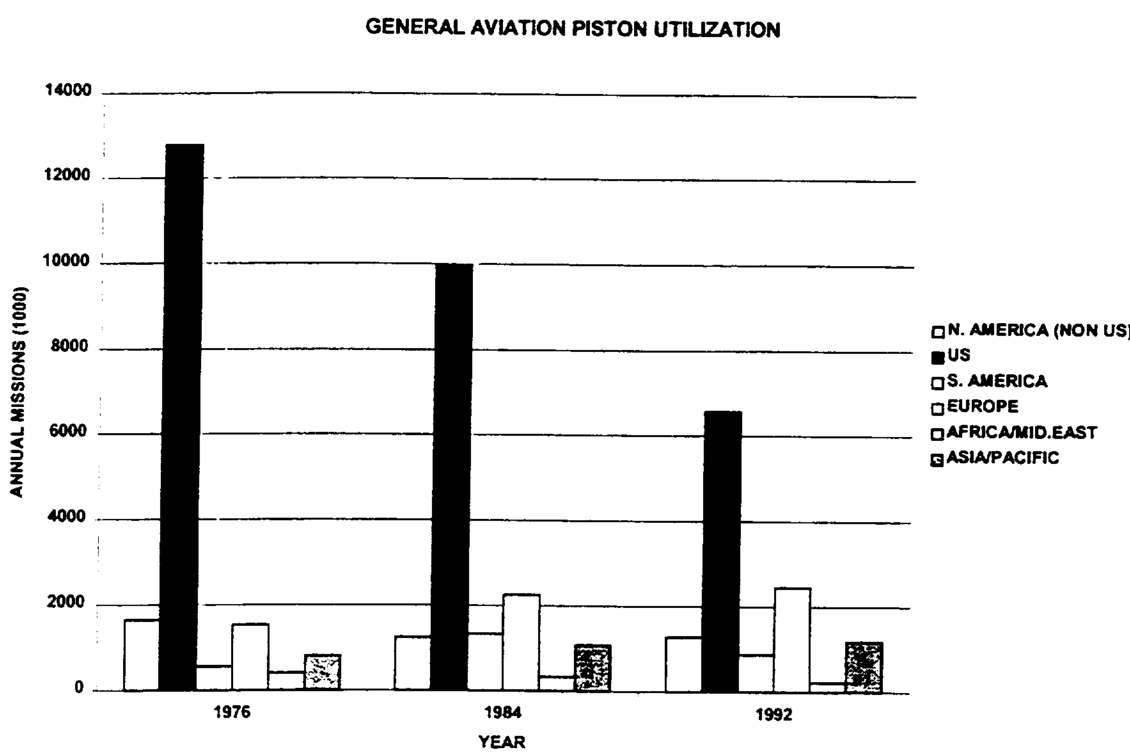


Figure 36 Regional comparison of General Aviation piston aircraft utilization

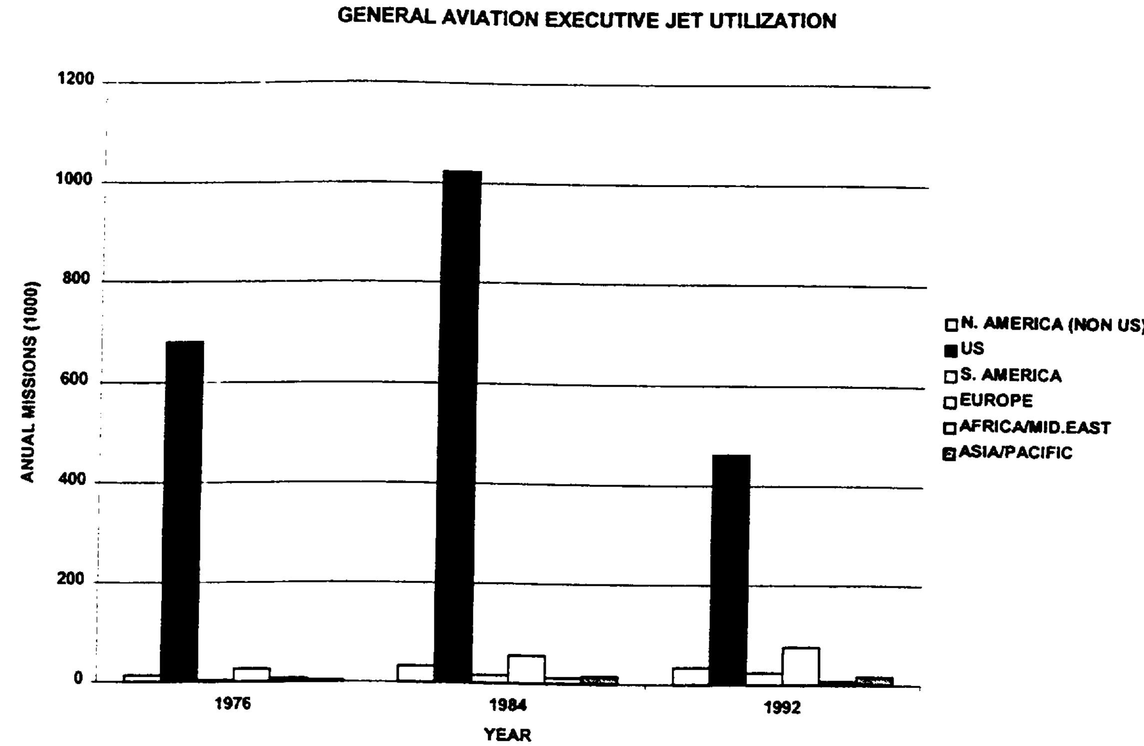


Figure 37 Regional comparison of General Aviation executive jet aircraft utilization

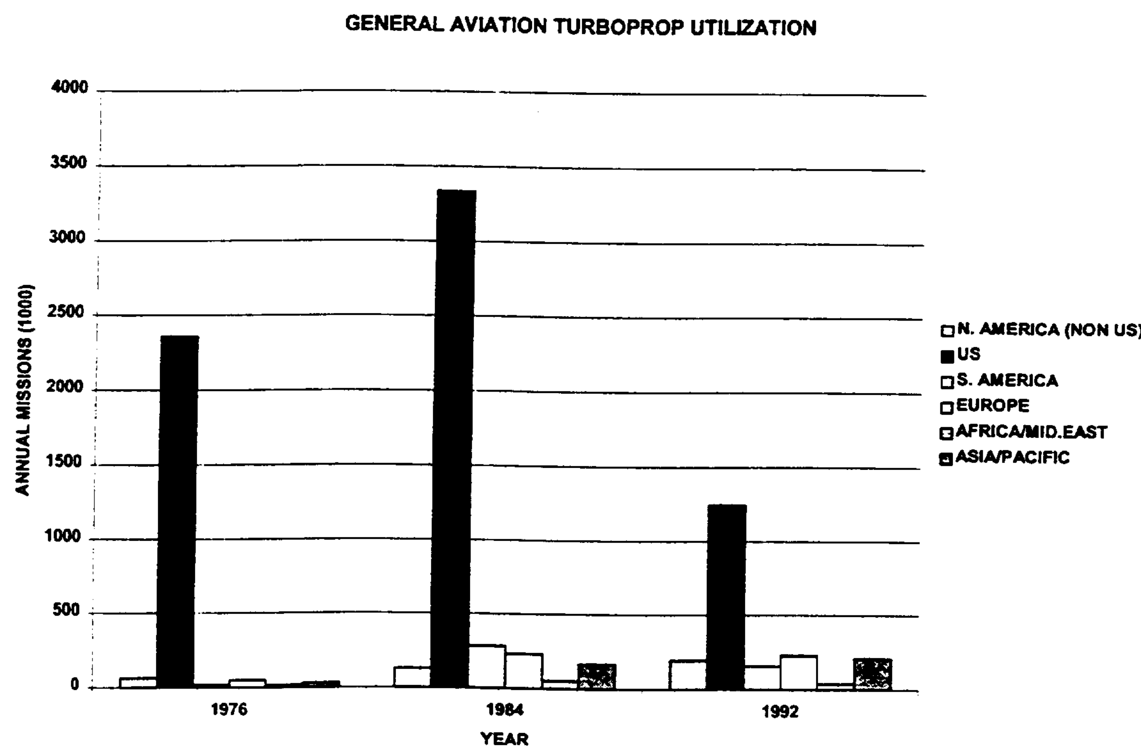


Figure 38 Regional comparison of General Aviation turboprop aircraft utilization

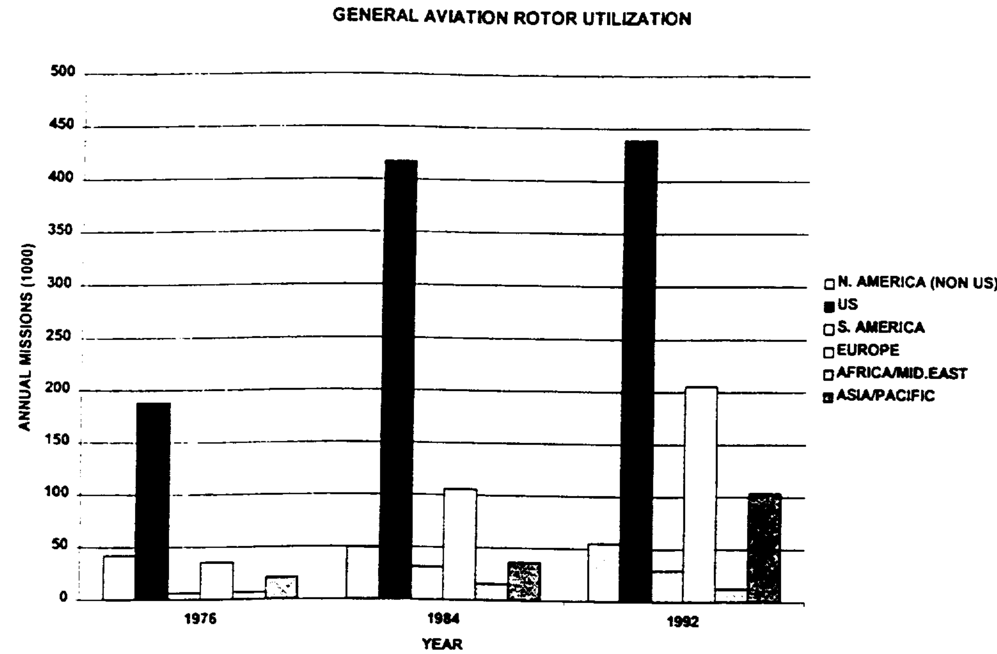


Figure 39 Regional comparison of General Aviation helicopter utilization

Although the GA piston class annually had the highest regional activity, a result primarily of the large inventory, it is not the largest consumer of GA fuel, ranking second to executive jets. The differentiation between these two classes in fuel usage is important in describing the overall GA emission inventories. As previously described, the executive jet class is more similarly modeled to a Charter class aircraft in both mission range, altitude and emission indices.

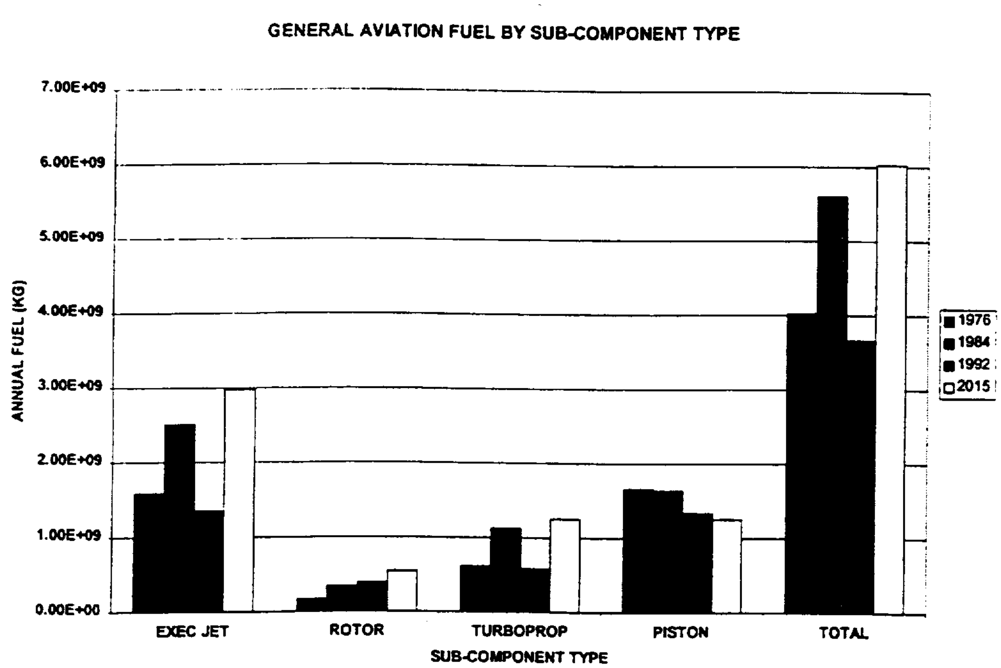


Figure 40 General Aviation fuel comparison by sub-component and year

The piston class, besides being short range and low altitude, is different in its aircraft/engine operational modes. The piston class mission during taxi, takeoff operates in a fuel rich mode, and to a lesser extent during initial climb, with high resulting CO emission indices (Teledyne Continental Motors, Reference 9, 1976). The fuel rich mode also exists during final descent and landing. The engine operational mode during the cruise mode is in a comparative lean condition. Nearly 40 percent of the piston class model mission occurs within the fuel rich operations mode. The overall effect of this on GA emission inventories are very localized, low altitude, high CO burdens.

Comparisons of GA NO_X and THC emissions for the scenario years are presented in Figure 41. Emissions of NO_X and THC indicate a gradual growth, with the exception of 1992, which was in a period general decline in GA operations (GAMA, General Aviation Statistical Databooks, Reference 23 through Reference 28). This was especially evident within the United States due to prevailing economic conditions. Since GA CO emissions are large, comparatively to NO_X and THC, comparisons of GA CO are shown in Figure 42. This figure illustrates the impact of the piston class on GA inventories. Overall GA CO is approximately one order of magnitude greater than the corresponding NO_X and THC. The decline in GA CO forecast in 1992 and 2015 is directly attributable to maintaining the size of the piston class fleet inventories with improved operational measures.

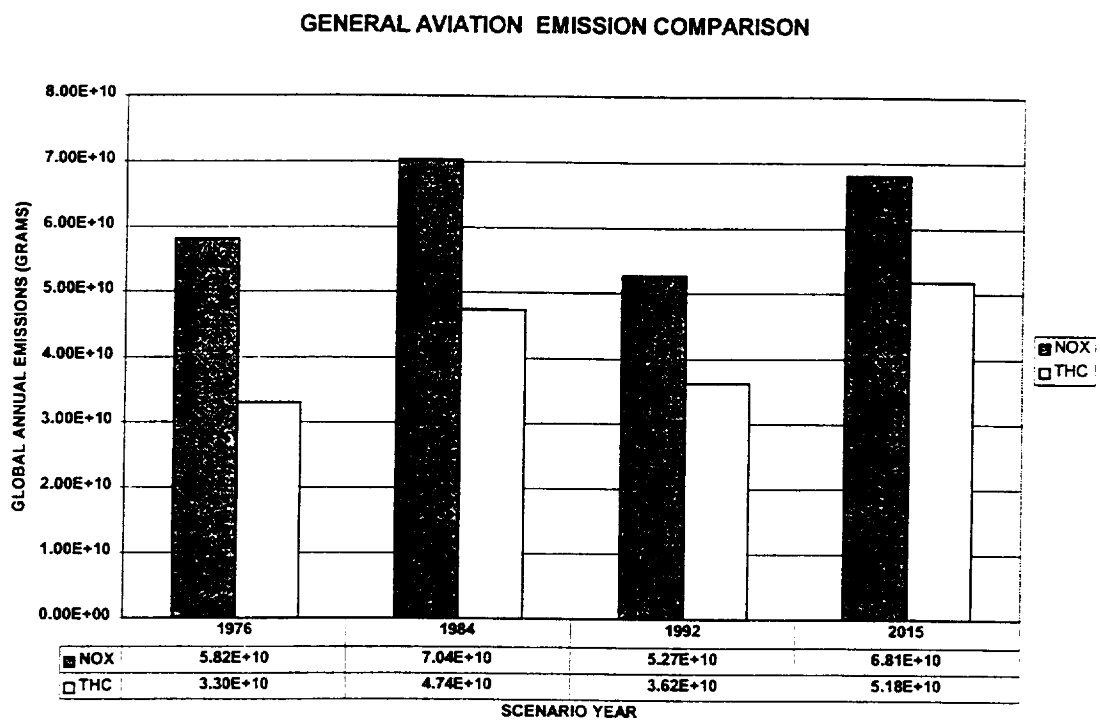


Figure 41 General Aviation NO_X and THC emission comparisons by scenario year

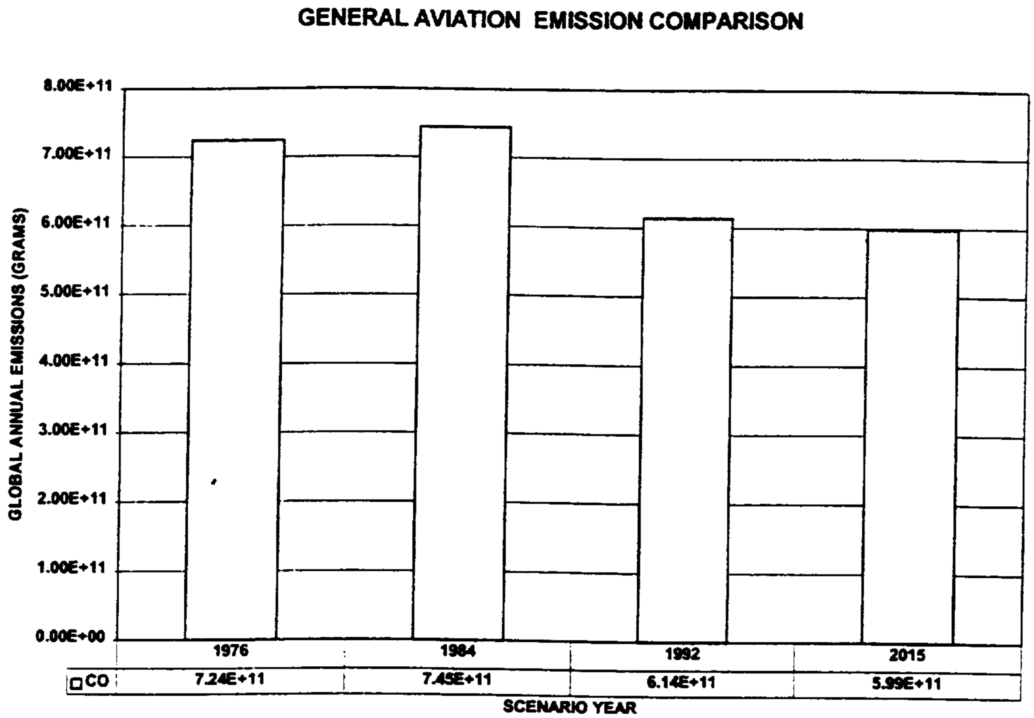


Figure 42 General Aviation CO emission comparisons by scenario year

Global annual emission distributions of General Aviation NO_X in the 1992 scenario year are presented in Figure 43 and Figure 44. Distributions are depicted as clustered in starburst form around the representative operating bases. This localization is only an outgrowth of the modeling of the basing. Since North America contains the largest inventories, especially the United States, distributions are heavily located in this area. The effect of a predominantly low altitude operations sector is shown in the altitude distribution. Peak altitude NO_X occurs under 5 kilometers for this component, with some $NO_{X\,d}$ distribution up to 14 kilometers occurring from the executive jet class.

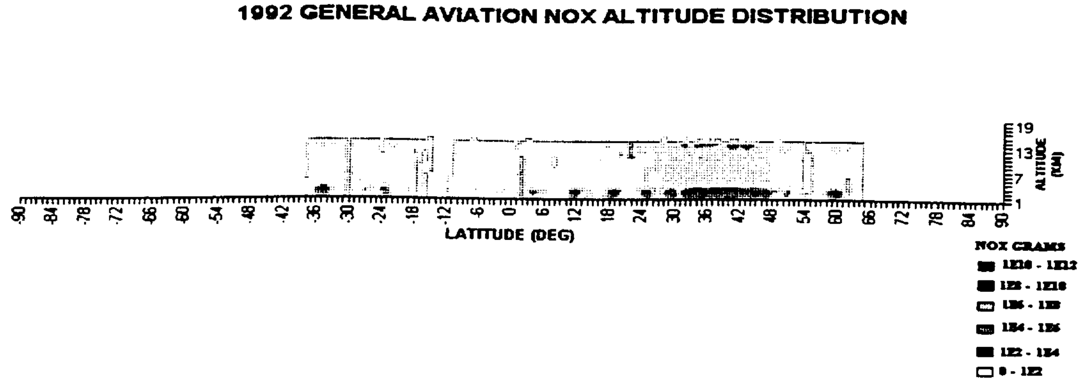


Figure 43 Altitude distribution of General Aviation NO_X in the 1992 scenario

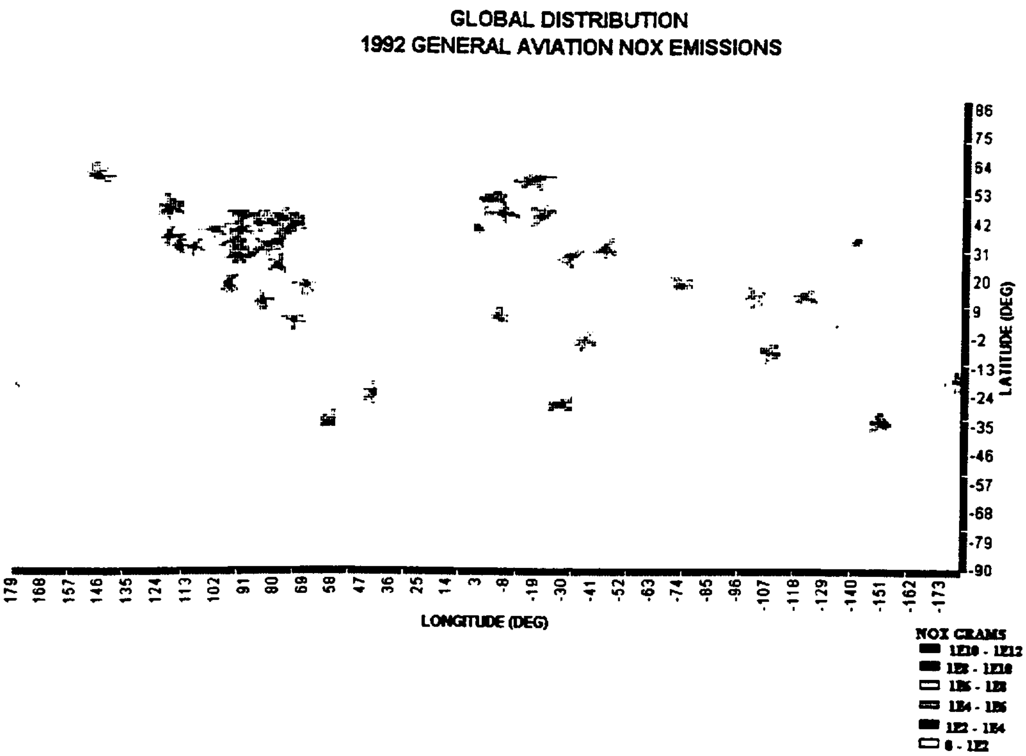


Figure 44 Geographic distribution of General Aviation NO_X in the 1992 scenario

Global annual emission distributions of 1992 GA CO are presented in Figure 45 and Figure 46. Geographic distributions again illustrate the starburst formations, but are more tightly clustered due to the short-range piston sub-class. The effect of the piston sub-class is especially evident with over half the CO emissions inventoried within the first kilometer. Although not shown, distributions of THC parallel the CO distributions but at lower magnitudes.

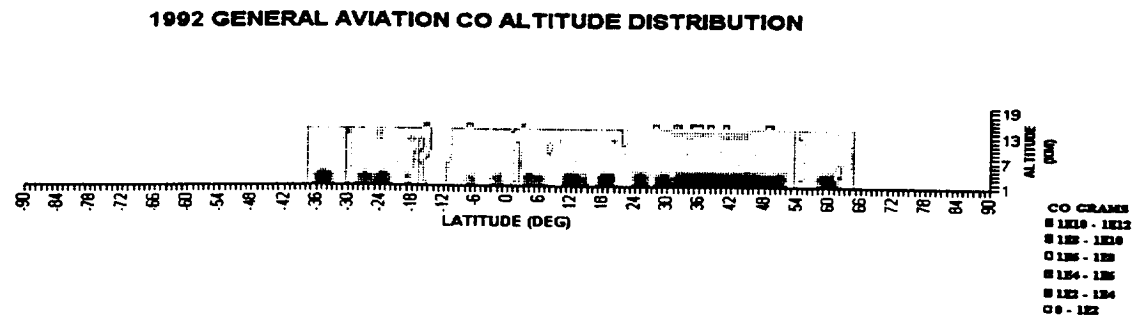


Figure 45 Altitude distribution of General Aviation CO in the 1992 scenario

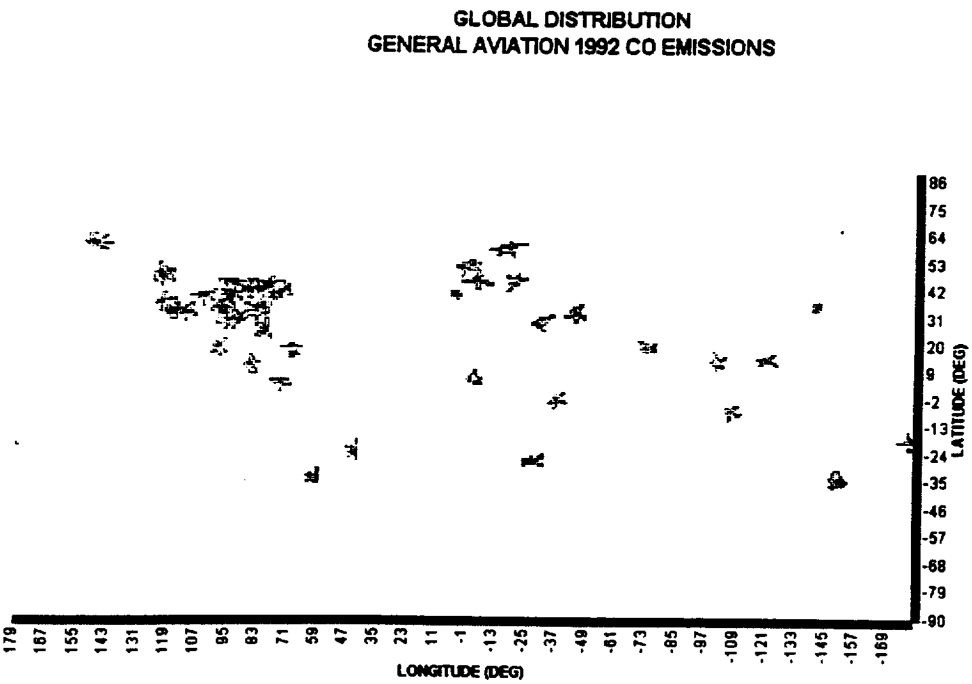


Figure 46 Geographic distribution of General Aviation CO in the 1992 scenario

Global annual emission distributions of GA NO_X for the forecast 2015 scenario year are presented in Figure 47 and Figure 48. Although the distributions continue to have a geographic starburst pattern, the impact of longer range executive jet routings is evident. The executive jet sub-class was permitted to utilize intercontinental range capability in 2015. Approximately 30 percent of this sub-class fuel budget were dedicated for such routes. Only notional routes between existing centroid bases were assigned. These routes do not reflect any perceived structure and were intended only to employ long-range capabilities. Peak altitude NO_X again occurs at altitudes less than 5 kilometers for this component. However the executive jet class provides further distributions of NO_X in the northern latitudes between 12 and 14 kilometers.

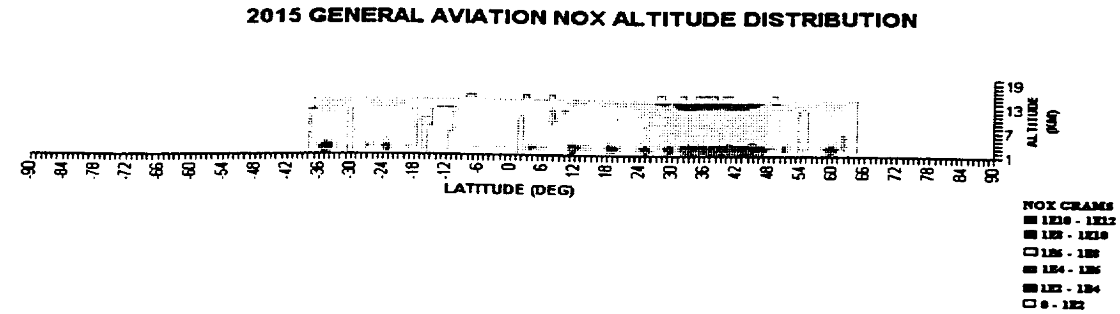


Figure 47 Altitude distribution of General Aviation NO_X in the 2015 scenario

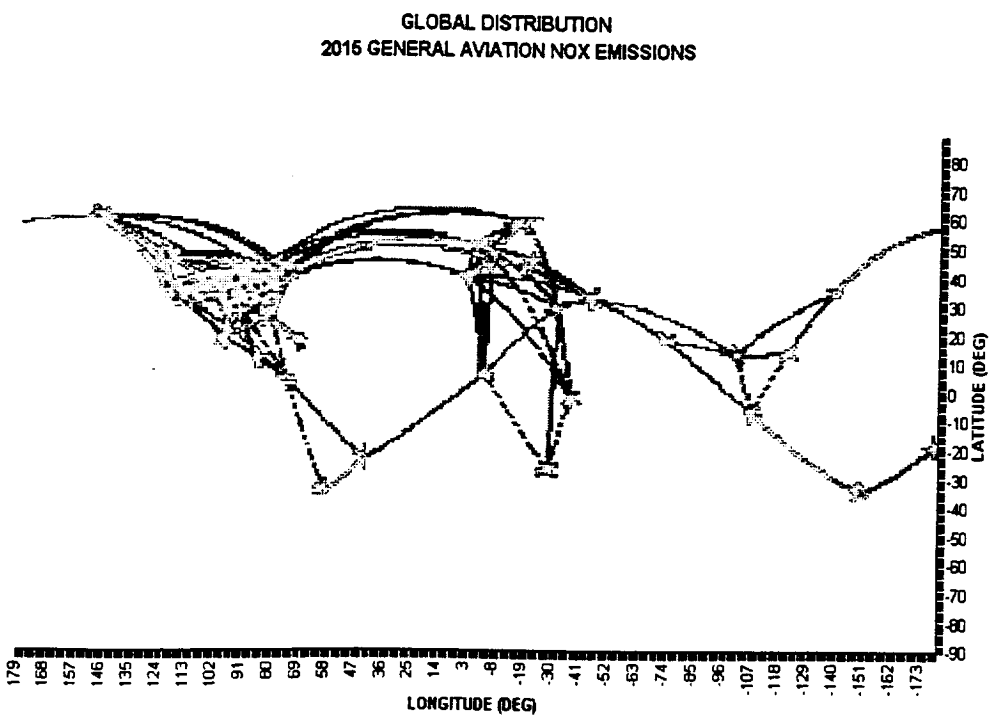


Figure 48 Geographic distribution of General Aviation NO_X in the 2015 scenario

Global annual emission distributions of GA for the forecast 2015 scenario year are presented in Figure 49 and Figure 50. The geographic distributions are similar to NO_X with the long range executive jet routings evident. Peak altitude NO_X again occurs under 5 kilometers for this component. The CO emissions remain driven by the piston sub-class, with over half the CO emissions inventoried within the first kilometer.

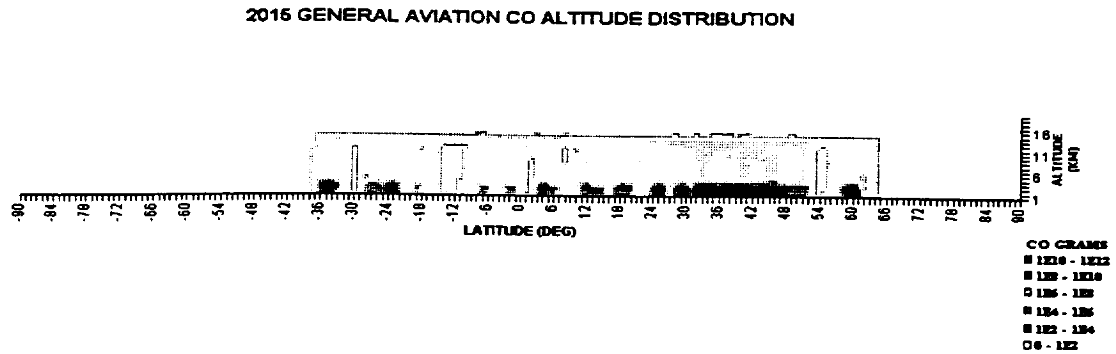


Figure 49 Altitude distribution of General Aviation CO in the 2015 scenario

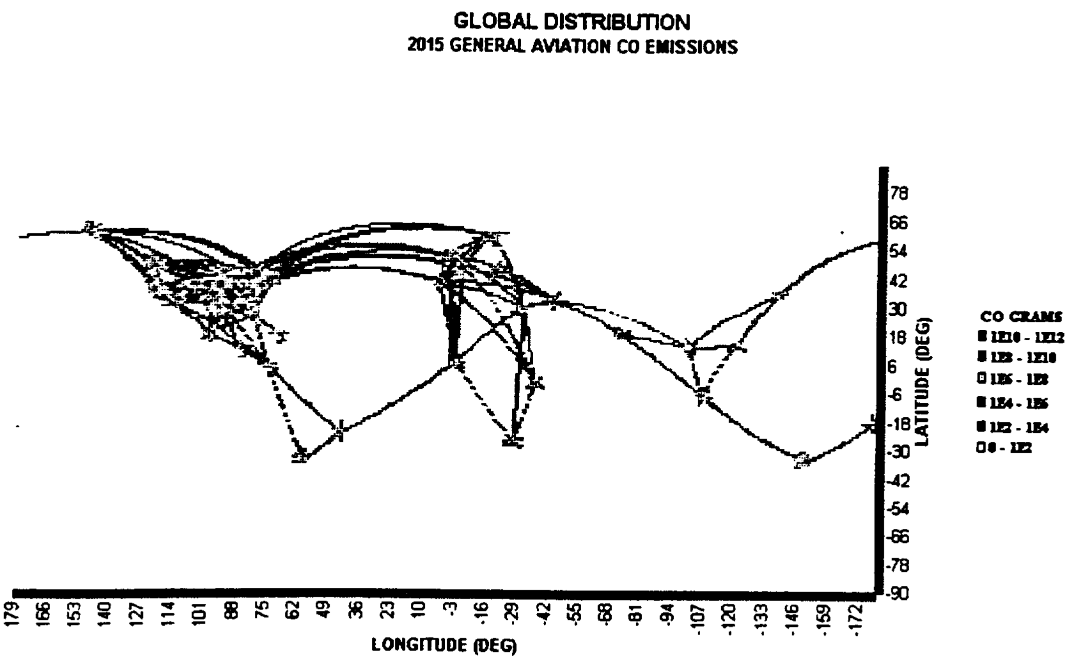


Figure 50 Geographic distribution of General Aviation CO in the 2015 scenario

Summary results of the GA component database fuel burn and emission estimates by altitude band for the four scenario years are presented in Table 14, Table 15, Table 16, and Table 17. For comparison and a historical record only, similar tabular results of the initially delivered databases are provided in Appendix A.

Table 14 2015 General Aviation Component Scenario Fuel Burn and Engine Exhaust Emission Estimates

Alt. Band (KM)	FUEL Kilograms ($x10^9$)	FUEL Cum. Fuel	NOX Grams ($x10^9$)	NOX Cum. Pct.	CO Grams ($x10^9$)	CO Cum. CO	THC Grams ($x10^9$)	THC Cum. THC	Emission Index (EI) NOX	Emission Index (EI) CO	Emission Index (EI) THC
1	1.27	21.0%	6.78	10.0%	302.45	50.5%	31.90	61.6%	5.35	238.52	25.16
2	1.00	37.7%	13.43	29.7%	102.92	67.7%	11.79	84.3%	13.40	102.67	11.76
3	1.15	56.7%	20.43	59.7%	175.70	97.1%	5.18	94.3%	17.82	153.20	4.51
4	0.20	60.0%	2.87	63.9%	12.70	99.2%	0.49	95.3%	14.30	63.37	2.43
5	0.15	62.6%	1.68	66.4%	0.35	99.3%	0.20	95.6%	10.86	2.24	1.26
6	0.15	65.2%	1.68	68.8%	0.35	99.3%	0.20	96.0%	10.86	2.24	1.26
7	0.15	67.7%	1.68	71.3%	0.35	99.4%	0.20	96.4%	10.86	2.24	1.26
8	0.15	70.3%	1.68	73.7%	0.34	99.4%	0.20	96.8%	10.86	2.23	1.26
9	0.15	72.8%	1.67	76.2%	0.34	99.5%	0.19	97.1%	10.87	2.19	1.26
10	0.15	75.3%	1.49	78.4%	0.35	99.6%	0.14	97.4%	9.86	2.30	0.95
11	0.15	77.8%	1.49	80.6%	0.31	99.6%	0.14	97.7%	9.90	2.06	0.91
12	0.15	80.3%	1.48	82.8%	0.30	99.7%	0.14	97.9%	9.91	2.03	0.91
13	0.46	87.9%	4.55	89.4%	0.83	99.8%	0.41	98.7%	9.90	1.80	0.90
14	0.73	100.0%	7.19	100.0%	1.25	100.0%	0.65	100.0%	9.90	1.72	0.90
TOTAL	**6.03**		**68.11**		**598.51**		**51.82**				

Table 15 1992 General Aviation Component Scenario Fuel Burn an Engine Exhaust Emission Estimates

Alt. Band (KM)	FUEL Kilograms ($x10^9$)	FUEL Cum. Fuel	NOX Grams ($x10^9$)	NOX Cum. Pct.	CO Grams ($x10^9$)	CO Cum. CO	THC Grams ($x10^9$)	THC Cum. THC	Emission Index (EI) NOX	Emission Index (EI) CO	Emission Index (EI) THC
1	0.91	24.8%	5.17	9.8%	319.28	52.0%	22.66	62.6%	5.7	350.7	24.9
2	0.69	43.6%	13.32	35.1%	102.43	68.7%	7.43	83.1%	19.4	149.0	10.8
3	0.88	67.6%	21.00	74.9%	176.68	97.4%	4.63	95.9%	23.8	200.5	5.3
4	0.13	71.2%	2.36	79.4%	14.13	99.7%	0.43	97.1%	17.9	107.2	3.3
5	0.08	73.3%	0.83	81.0%	0.09	99.8%	0.09	97.3%	11.0	1.2	1.2
6	0.08	75.4%	0.84	82.6%	0.09	99.8%	0.09	97.6%	11.0	1.2	1.2
7	0.08	77.5%	0.84	84.2%	0.09	99.8%	0.09	97.8%	11.0	1.2	1.2
8	0.08	79.5%	0.84	85.7%	0.09	99.8%	0.09	98.1%	11.0	1.2	1.2
9	0.08	81.6%	0.83	87.3%	0.09	99.8%	0.09	98.3%	11.0	1.2	1.2
10	0.08	83.7%	0.75	88.7%	0.13	99.8%	0.07	98.5%	9.9	1.7	0.9
11	0.08	85.7%	0.75	90.2%	0.13	99.9%	0.07	98.7%	9.9	1.7	0.9
12	0.08	87.8%	0.75	91.6%	0.13	99.9%	0.07	98.9%	9.9	1.7	0.9
13	0.18	92.8%	1.82	95.0%	0.31	99.9%	0.17	99.3%	9.9	1.7	0.9
14	0.26	100.0%	2.61	100.0%	0.45	100.0%	0.24	100.0%	9.9	1.7	0.9
TOTAL	**3.66**		**52.70**		**614.12**		**36.21**				

Table 16 1984 General Aviation Component Scenario Fuel Burn and Engine Exhaust Emission Estimates

Alt. Band	FUEL		NOX		CO		THC		Emission Index (EI)		
(KM)	Kilograms ($x10^9$)	Cum. Fuel	Grams ($x10^9$)	Cum. NOX	Grams ($x10^9$)	Cum. CO	Grams ($x10^9$)	Cum. THC	NOX	CO	THC
1	1.16	20.7%	6.40	9.1%	374.61	50.3%	27.67	58.4%	5.5	322.8	23.9
2	1.00	38.6%	15.69	31.4%	124.17	67.0%	11.04	81.7%	15.6	123.7	11.0
3	1.29	61.7%	25.16	67.2%	226.77	97.4%	6.16	94.7%	19.5	175.6	4.8
4	0.20	65.3%	3.07	71.5%	16.12	99.6%	0.55	95.9%	15.3	80.4	2.7
5	0.14	67.7%	1.53	73.7%	0.17	99.6%	0.17	96.2%	11.0	1.2	1.2
6	0.14	70.2%	1.53	75.9%	0.17	99.6%	0.17	96.6%	11.0	1.2	1.2
7	0.14	72.7%	1.53	78.0%	0.17	99.7%	0.17	96.9%	11.0	1.2	1.2
8	0.14	75.2%	1.53	80.2%	0.17	99.7%	0.17	97.3%	11.0	1.2	1.2
9	0.14	77.7%	1.53	82.4%	0.17	99.7%	0.17	97.6%	11.0	1.2	1.2
10	0.14	80.2%	1.38	84.4%	0.24	99.7%	0.13	97.9%	9.9	1.7	0.9
11	0.14	82.7%	1.38	86.3%	0.24	99.8%	0.13	98.2%	9.9	1.7	0.9
12	0.14	85.1%	1.38	88.3%	0.24	99.8%	0.13	98.4%	9.9	1.7	0.9
13	0.34	91.2%	3.38	93.1%	0.58	99.9%	0.31	99.1%	9.9	1.7	0.9
14	0.49	100.0%	4.87	100.0%	0.84	100.0%	0.44	100.0%	9.9	1.7	0.9
TOTAL	5.60		70.36		744.63		47.39				

Table 17 1976 General Aviation Component Scenario Furl Burn and Engine Exhaust Emission Estimates

Alt. Band (KM)	FUEL Kilograms ($x10^9$)	FUEL Cum. Fuel	NOX Grams ($x10^9$)	NOX Cum. NOX	CO Grams ($x10^9$)	CO Cum. CO	THC Grams ($x10^9$)	THC Cum. THC	Emission Index (EI) NOX	Emission Index (EI) CO	Emission Index (EI) THC
1	0.82	20.4%	4.82	8.3%	363.25	50.2%	18.68	56.6%	5.9	442.8	22.8
2	0.72	38.4%	14.11	32.5%	116.22	66.2%	6.84	77.3%	19.5	160.6	9.4
3	1.10	65.7%	24.06	73.9%	226.72	97.5%	5.78	94.8%	21.9	206.3	5.3
4	0.15	69.4%	2.49	78.2%	16.05	99.7%	0.48	96.2%	16.8	108.3	3.3
5	0.09	71.6%	0.97	79.9%	0.11	99.8%	0.11	96.6%	11.0	1.2	1.2
6	0.09	73.7%	0.97	81.5%	0.11	99.8%	0.11	96.9%	11.0	1.2	1.2
7	0.09	75.9%	0.97	83.2%	0.11	99.8%	0.11	97.2%	11.0	1.2	1.2
8	0.09	78.1%	0.97	84.9%	0.11	99.8%	0.11	97.5%	11.0	1.2	1.2
9	0.09	80.3%	0.97	86.5%	0.11	99.8%	0.11	97.8%	11.0	1.2	1.2
10	0.09	82.5%	0.87	88.0%	0.15	99.8%	0.08	98.1%	9.9	1.7	0.9
11	0.09	84.7%	0.87	89.5%	0.15	99.9%	0.08	98.3%	9.9	1.7	0.9
12	0.09	86.9%	0.87	91.0%	0.15	99.9%	0.08	98.6%	9.9	1.7	0.9
13	0.22	92.2%	2.14	94.7%	0.37	99.9%	0.19	99.1%	9.9	1.7	0.9
14	0.31	100.0%	3.09	100.0%	0.53	100.0%	0.28	100.0%	9.9	1.7	0.9
TOTAL	4.02		58.17		724.12		33.02				

6.0 SUMMARY

MDC modeled global aircraft operations to estimate fuel burn and emission levels (NO_X ,CO, and THC) for the military, charter, unreported domestic and general aviation components for the years 1976, 1984, 1992 and a forecast 2015 scenario. These databases are available for atmospheric modeling studies being conducted by the Atmospheric Effects of Aviation Project (AEAP) investigation and are in the form of a 1°latitude x 1°longitude x 1 kilometer altitude grid.

The methods used in this study have been improved to reflect the use of the Boeing Method 2 emission index corrections for ambient temperature, pressure, humidity and aircraft speed. In addition, the general aviation component estimates, which previously had not been addressed, were developed for all scenario years.

The four aviation components discussed in this report represent a relatively small percentage of the overall aviation emissions. The four MDC components combined represent only 32 percent of the total aviation fuel consumed and 26 percent of aviation NO_X for 1992. The scheduled aviation component is forecast to increase substantially by 2015. As a result the contribution of the four components in 2015 is further reduced. In 2015 these components in represent only 18 percent and 13 percent of aviation fuel and NO_X respectively

Generalized comments can be drawn from each of the individual components. The military component is observed to have a significant continuous reduction in total fuel burn. Estimates for 1976 show a global annual fuel consumption of 35.1 x 10^9 kilograms (an average daily 9.7 x 10^7 kilograms), decreasing in 1992 by 25 percent (26.5 x 10^9 kilograms annually/ 7 x 10^7 kilograms daily average) and with a further forecast reduction to an annual 20.6 x 10^9 kilograms (5.6 x 10^7 kilograms daily average) in 2015. These reductions are a direct result of the scale-back of world military forces. Both the charter and unreported domestic traffic have an increasing fuel burn. The charter is estimated to grow an average 4 percent annually (8.3 x 10^9 annual kilograms/ 2.3 x 10^7 kilograms daily average in 1976, to a forecast 13.5 x 10^9 annual kilograms/ 3.7 x 10^7 kilograms daily average in 2015). The unreported domestic traffic growth is somewhat more robust growing nearly an average 7 percent (6 x 10^9 annual kilograms/ 1.6 x 10^7 kilograms daily average in 1976 to 15.8 x 10^9 annual kilograms/ 4.3 x 10^7 kilograms daily average forecast in 2015). These two component fuel burns respond to passenger traffic demands, which are reflective of a trend of continued economic growth. The general aviation component represented the smallest aviation fuel consumption component. This component was estimated to grow an annual average of 4 percent, from an estimated annual 4.0 x 10^9 kilograms/ 1.1 x 10^7 kilograms daily average in. 1976 to a forecast 6.0 x 10^9 annual kilograms/ 1.6 x 10^7 kilograms daily average in 2015. General aviation however is a significant contributor to aviation CO providing nearly 39 percent (6.1 x 10^8 annual kilograms/ 1.6 x 10^6 kilograms daily average) of the total CO inventoried in 1992. The CO production is mainly attributable to the piston engine sub-class, which has engine operational regimes that are fuel rich. General aviation, in 2015, is forecast to reduce annual CO production to 6.0 x 10^8 kilograms/ 1.6 x 10^6 kilograms daily average, which would then represent 26 percent of aviation CO.

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Appendix A

List of Tables Within Appendix A

Table of Figures Within Appendix A

This appendix contains data used to generate the estimated fuel consumption and emissions for each of the components detailed in this report. Both Appendix A Table 1 and Appendix A Table 2 provide military inventories for 1984 and 1976 developed from assimilating data from various sources (International Institute for Strategic Studies, Reference 30 through Reference 33, 1989-75).

Appendix A Table 1 Military inventory for the scenario year 1984 by region and country

1984 Military Inventory Region/Alliance/Country	MISSION FIGHTER	 TRANSPORT	 BOMBER	 TRAINER	 OTHER	 TOTAL
CIS						
CIS Air Force	6475	605	598	680	415	8773
CIS Navy	75	200	287		340	902
CIS Subtotal	6550	805	885	680	755	9675
US						
US Air Force	3130	1246	448	1755	1113	7692
US Navy	1369	129		598	996	3092
US Subtotal	4499	1375	448	2353	2109	10784
Asia/Australia						
Afghanistan	127	39	20	42		228
Australia	76	54		134	64	328
Bangladesh	21	5		24		50
Brunei					2	2
Burma	2	19		30	16	67
Cambodia						0
Guam					20	20
India	676	179	35	243	45	1178
Indonesia	61	47		55	18	181
Japan	253	68		282	140	743
Laos	20	18				38
Malaysia	29	43		27	3	102
Mongolia	12	40		5		57
Nepal		4				4
New Zealand	28	16		22	12	78
North Korea	380	270	70	220		940
Pakistan	235	18	11	170	64	498
Papua New Guinea		10				10
Philippines	56	81		52	48	237
Singapore	74	14		61	32	181
South Korea	170	35		206	30	441
Sri Lanka		12		14	6	32
Taiwan	350	106		112	51	619
Thailand	168	28		73	69	338
Vietnam	287	55		60		402
Asia/Australia Subtotal	3025	1161	136	1832	620	6774

1984 Military Inventory Region/Alliance/Country	MISSION FIGHTER	 TRANSPORT	 BOMBER	 TRAINER	 OTHER	 TOTAL
NATO						
Belgium	126	26		83	18	253
Canada	104	65		199	66	434
Denmark	80	6		30	24	140
France	439	230	230	439	22	1360
Greece	237	113		136	44	530
Iceland						0
Italy	194	215		215	89	713
Luxembourg					4	4
Netherlands	126	12		38	27	203
Norway	85	13		33	13	144
Portugal	70	17		100	10	197
Spain	186	132		235	32	585
Turkey	320	144		209	38	711
UK	343	65		343	103	854
West Germany	461	240		43	87	831
NATO Subtotal	2771	1278	230	2103	577	6959
China						
China Air Force	4130	315	670		130	5245
China Navy	600	60	151		11	822
China Subtotal	4730	375	821	0	141	6067
Middle East/North Africa						
Algeria	283	38	12	13	11	357
Bahrain						0
Djibouti	10	4		1		15
Egypt	469	66	14	246	45	840
Iran	167	85		54	5	311
Iraq	313	58	17	119	8	515
Israel	523	119		208	33	883
Jordan	83	16		28		127
Kuwait	49	7		9		65
Lebanon	8	2		11		21
Libya	419	44	7	294	7	771
Mauritania						0
Morocco	98	31		74	7	210
North Yemen	75	13		8		96
Oman	33	33		12	4	82
Qatar	11	4				15
Saudi Arabia	124	66		104	6	300
Somalia						0
South Yemen	42		10	3		55
Sudan	31	25		18		74
Syria	457	25		160		642

1984 Military Inventory Region/Alliance/Country	FIGHTER	TRANSPORT	BOMBER	TRAINER	OTHER	TOTAL
Tunisia	8	5		48		61
United Arab Emirates	43	24		16		83
Middle East/North Africa Subtotal	3246	665	60	1426	126	5523
Caribbean/Latin America						
Argentina	176	174	8	148	56	562
Bahamas						0
Belize						0
Bolivia	22	61		54	1	138
Brazil	150	70		189	140	549
Chile	80	111		91	4	286
Colombia	28	45		88	12	173
Costa Rica						0
Cuba	250	93		43		386
Dominican Republic	19	7		30		56
Ecuador	51	47	3	32	80	213
El Salvador	32	14		26	4	76
Falkland Islands						0
Guatemala	16	40		25		81
Guyana		10				10
Haiti	8	12		5		25
Honduras	26	21		19		66
Jamaica		5				5
Mexico	77	58		98	48	281
Nicaragua	10	6				16
Panama						0
Paraguay	20	36		43		99
Peru	90	63	12	77	13	255
Suriname						0
Trinidad		1				1
Uruguay	18	25		53	21	117
Venezuela	62	55	20	55	9	201
Caribbean/Latin America Subtotal	1135	954	43	1076	388	3596
Warsaw Pact						
Bulgaria	224	25		25	24	298
Czechoslovakia	416	49		49	55	569
German Democratic Republic	347	36		36	12	431
Hungary	140	27		27		194
Poland	689	42		42	65	838
Romania	297	30		30	18	375
Warsaw Pact Subtotal	2113	209	0	209	174	2705
Sub-Sahara Africa						
Angola	66	57		13	1	137
Benin		13		1		14

1984 Military Inventory Region/Alliance/Country	MISSION FIGHTER	TRANSPORT	BOMBER	TRAINE R	OTHER	TOTAL
Botswana	5	2		8		15
Burundi	3	5				8
Cameroon	10	21			2	33
Cape Verde		2				2
Central African Republic		29				29
Chad		30				30
Congo	21	17		4		42
Cote D'Ivorie	5	22		2		29
Equatorial Guinea	2	4				6
Ethiopia	107	21		1		129
Gabon	11	27		8	1	47
Ghana	10	31				41
Guinea	6	14		10		30
Guinea-Bissau		5				5
Kenya	28	18		17		63
Liberia		2		14		16
Madagascar	12	17				29
Malawi		12				12
Mali	5	8		7		20
Mauritania	7	5				12
Mozambique	35	15		7		57
Niger		15		2		17
Nigeria	30	59		24		113
Rwanda	2	6		1		9
Senegal		17		5	2	24
Seychelles		4				4
South Africa	308	86	14	198	23	629
Tanzania	29	11		16		56
Togo	11	4		5		20
Upper Volta		13				13
Zaire	19	48		49		116
Zambia	51	26		47		124
Zimbabwe	22	18	7	24		71
Sub-Sahara Africa Subtotal	805	684	21	463	29	2002
Non-Aligned Europe						
Albania	100	14		10		124
Austria	32			57		89
Cyprus						0
Finland	42	11		119		172
Ireland	16	12			6	34
Sweden	332	78		239	122	771
Switzerland	248	49		115	23	435
Yugoslavia	345	65		93	35	538
Non-Aligned Europe Subtotal	1115	229	0	633	186	2163

1984 Military Inventory Region/Alliance/Country	MISSION FIGHTER	TRANSPORT	BOMBER	TRAINER	OTHER	TOTAL
Global Total	**29989**	**7735**	**2644**	**10775**	**5105**	**56248**
Global Mission Distribution	50.1%	12.9%	4.4%	18.0%	8.5%	100.0%

Appendix A Table 2 Military inventories for the 1976 scenario year by region and country

1976 Military Inventory Region/Alliance/Country	MISSION FIGHTER	TRANSPORT	BOMBER	TRAINER	OTHER	TOTAL
CIS						
CIS Air Force	5700	1540	805	350	50	8445
CIS Navy		200	400		285	885
CIS Subtotal	5700	1740	1205	350	335	9330
US						
US Air Force	2466	1272	448	1564	1178	6928
US Navy	1436	129		455	716	2736
US Subtotal	3902	1401	448	2019	1894	9664
Asia/Australia						
Afghanistan	130	25	30			185
Australia	74	63		135	42	314
Bangladesh	14	4		3		21
Burma		28		41	11	80
Cambodia						0
India	700	220	50	52	26	1048
Indonesia	45	52	2			99
Japan	430	72		370	135	1007
Laos	75	35		5		115
Malaysia	20	35		14	20	89
Mongolia		30				30
Nepal						0
New Zealand	13	22		65	5	105
North Korea	518	150	60	129	10	867
Pakistan	259	19	10	5	9	302
Papua New Guinea						0
Philippines	36	65		62	16	179
Singapore	64	12		12	29	117
South Korea	206	44		74	10	334
Sri Lanka		6		17	18	41
Taiwan	198	85		125	18	426

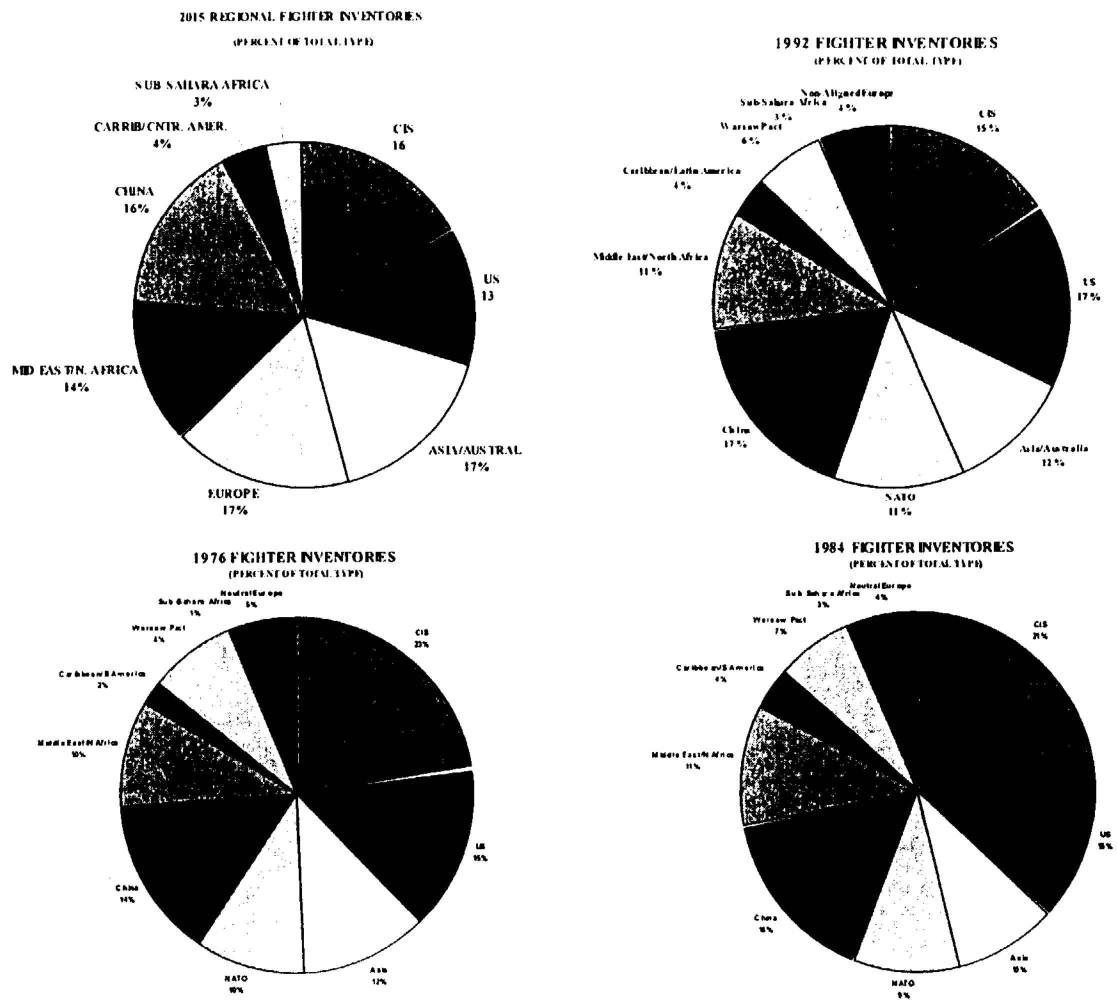
1976 Military Inventory Region/Alliance/Country	MISSION FIGHTE R	TRANSPORT	BOMBER	TRAINER	OTHER	TOTAL
Thailand	10	35		75	100	220
Vietnam	260	56	8	30		354
Asia/Australia Subtotal	3052	1058	160	1214	449	5933
NATO						
Belgium	126	29			18	173
Canada	64	65		13	76	218
Denmark	100	13			23	136
France	449	177	51		128	805
Greece	206	47		103	44	400
Iceland						0
Italy	254	46		275	266	841
Luxembourg						0
Netherlands	144	24		44	41	253
Norway	113	10		22	18	163
Portugal	57	103	13	198	60	431
Spain	86	60		203	105	454
Turkey	232	148		115	60	555
UK	146	104	50		111	411
West Germany	480	111			105	696
NATO Subtotal	2457	937	114	973	1055	5536
China						
China Air Force	3250	250	460			3960
China Navy	400		100			500
China Subtotal	3650	250	560	0	0	4460
Middle East/North Africa						
Algeria	135	11	25		26	197
Bahrain						0
Djibouti						0
Egypt	563	70	30	350		1013
Iran	221	84		124	23	452
Iraq	240	30	7	30		307
Israel	475	97		110	8	690
Jordan	42	11		28		81
Kuwait	32	5		6		43
Lebanon	19				11	30
Libya	82	17		13	10	122
Mauritania						0
Morocco	48	24		94	3	169
North Yemen	12	3	12	15		42
Oman	31	31			16	78
Qatar	13	1				14
Saudi Arabia	65	25		23	30	143

1976 Military Inventory Region/Alliance/Country	MISSION FIGHTER	TRANSPORT	BOMBER	TRAINER	OTHER	TOTAL
Somalia						0
South Yemen	27	4				31
Sudan	33	15				48
Syria	390	9	10			409
Tunisia	12	3		32	12	59
United Arab Emirates	26	9			3	38
Middle East/North Africa Subtotal	2466	449	84	825	142	3966
Caribbean/Latin America						
Argentina	109	10	11		12	142
Bahamas						0
Belize						0
Bolivia	15	30		47	22	114
Brazil	16	130		145	270	561
Chile	32	72		75	32	211
Colombia	16	125				141
Costa Rica						0
Cuba	205	70		85		360
Dominican Republic	30	12		8	2	52
Ecuador	19	59	5	63	120	266
El Salvador	12	14				26
Falkland Islands						0
Guatemala	8	11		3		22
Guyana		2		2		4
Haiti	6	5		6		17
Honduras	4	9			6	19
Jamaica						0
Mexico		43		115	33	191
Nicaragua		7	5	5	6	23
Panama						0
Paraguay		14			13	27
Peru	62	79	24	81	8	254
Suriname						0
Trinidad						0
Uruguay	6	31		18	6	61
Venezuela	35	39	30	75	32	211
Caribbean/Latin America Subtotal	575	762	75	728	562	2702
Warsaw Pact						
Bulgaria	216	24			69	309
Czechoslovakia	408	30		626	50	1114
German Democratic Republic	330	34				364
Hungary	108	30				138
Poland	734	50	15		82	881
Romania	244	30			10	284
Warsaw Pact Subtotal	2040	198	15	626	211	3090

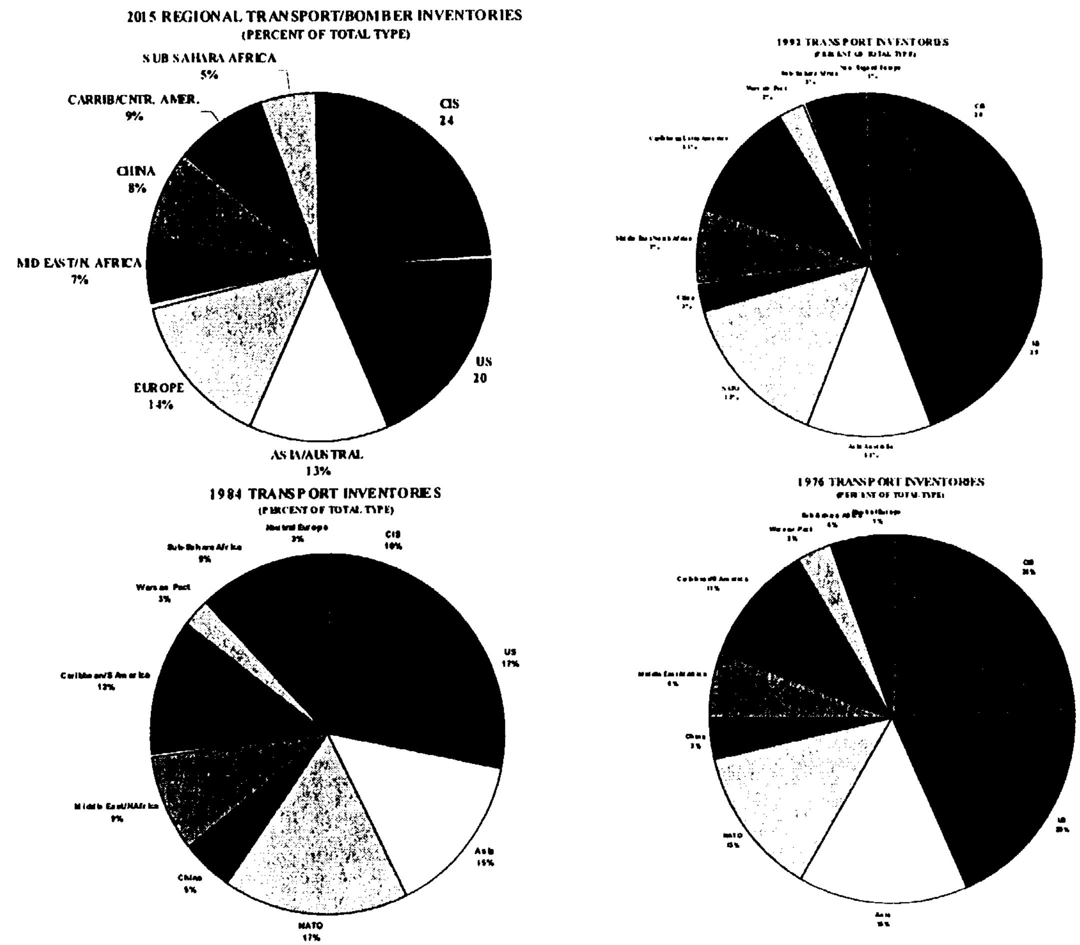
1976 Military Inventory Region/Alliance/Country	MISSION FIGHTER	TRANSPORT	BOMBER	TRAINER	OTHER	TOTAL
Sub-Sahara Africa						
Angola				13		13
Benin				1		1
Botswana				8		8
Burundi		4				4
Cameroon	6	5				11
Cape Verde						0
Central African Republic						0
Chad	5					5
Congo				4	7	11
Cote D'Ivorie		2		2		4
Equatorial Guinea						0
Ethiopia	19	16	4	1	14	54
Gabon				8		8
Ghana	6	27				33
Guinea	15	10		10		35
Guinea-Bissau						0
Kenya	4	13		17	5	39
Liberia		2		14		16
Madagascar		3				3
Malawi		6				6
Mali	7	4		7		18
Mauritania		2				2
Mozambique				7		7
Niger		5		2		7
Nigeria	21	6		24	20	71
Rwanda		6		1		7
Senegal		4		5		9
Seychelles						0
South Africa	109	62	22	198	45	436
Tanzania	20	19		16		55
Togo		1		5		6
Upper Volta		6				6
Zaire	42	35		49	40	166
Zambia		33		47	24	104
Zimbabwe	19	17	9	24	12	81
Sub-Sahara Africa Subtotal	273	288	35	463	167	1226
Non-Aligned Europe						
Albania	96	6				102
Austria	38	4		43		85
Cyprus						0
Finland	47	10		29		86
Ireland	16	10				26
Sweden	600	10			168	778
Switzerland	276	3		161	15	455

1976 Military Inventory	MISSION					
Region/Alliance/Country	FIGHTER	TRANSPORT	BOMBER	TRAINER	OTHER	TOTAL
Yugoslavia	230	56		90	40	416
Non-Aligned Europe Subtotal	1303	99	0	323	223	1948
Global Total	**25418**	**7182**	**2696**	**7521**	**5038**	**47855**
Global Mission Distribution	53.1%	15.0%	5.6%	15.7%	10.5%	100.0%

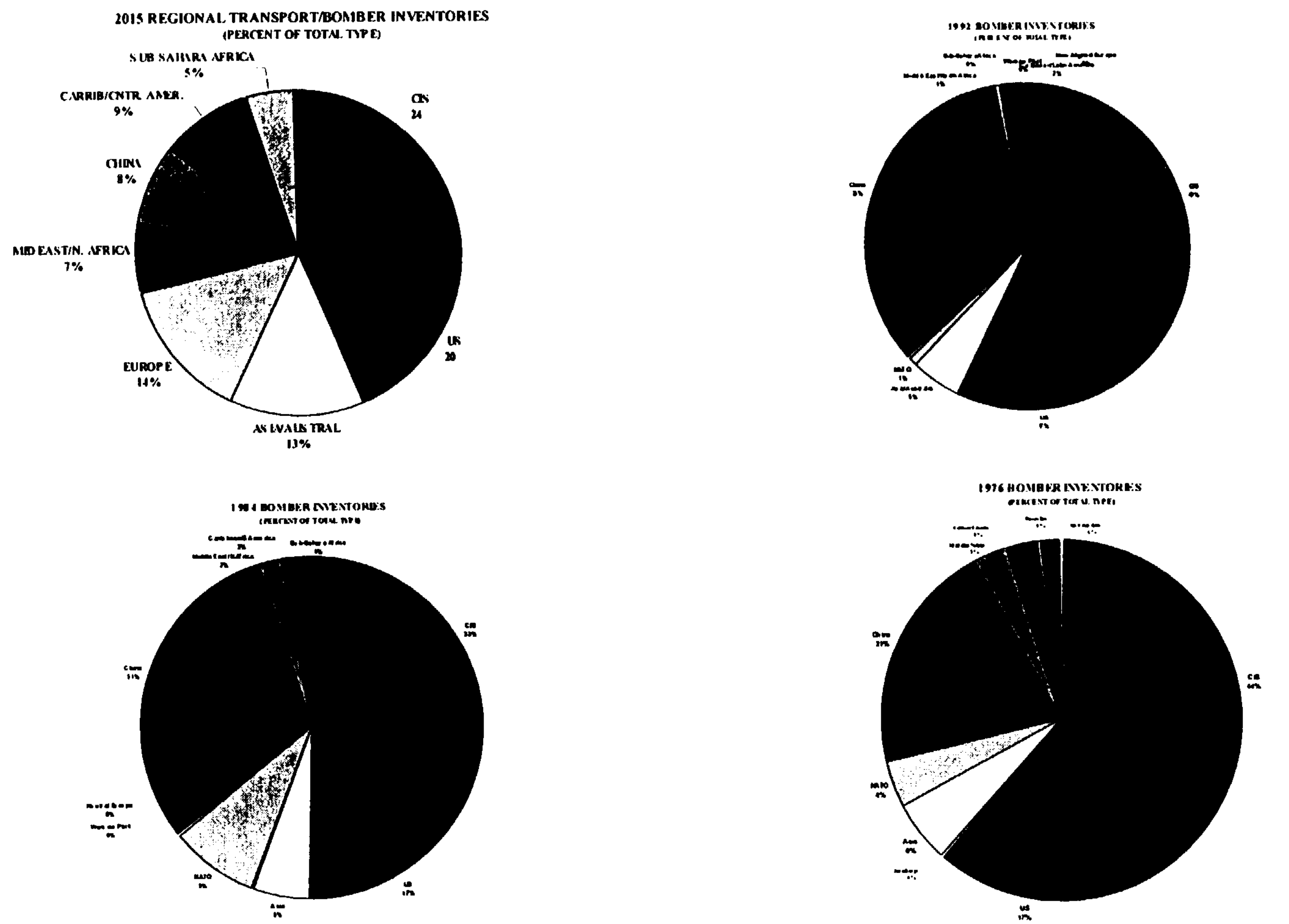
Comparisons of military mission category regional variations for each of the study years is shown in Appendix A Figure 1 through Appendix A Figure 5 using both data from the above tables and previous publications (Ward, Reference 1, 1994, Metwally, Reference 2, 1995, International Institute for Strategic Studies, Reference 30, 1991, Forecast International/DMS, Reference 35,1992, Nation, Reference 36, 1992, and International Media Corporation, Reference 37, 1990).



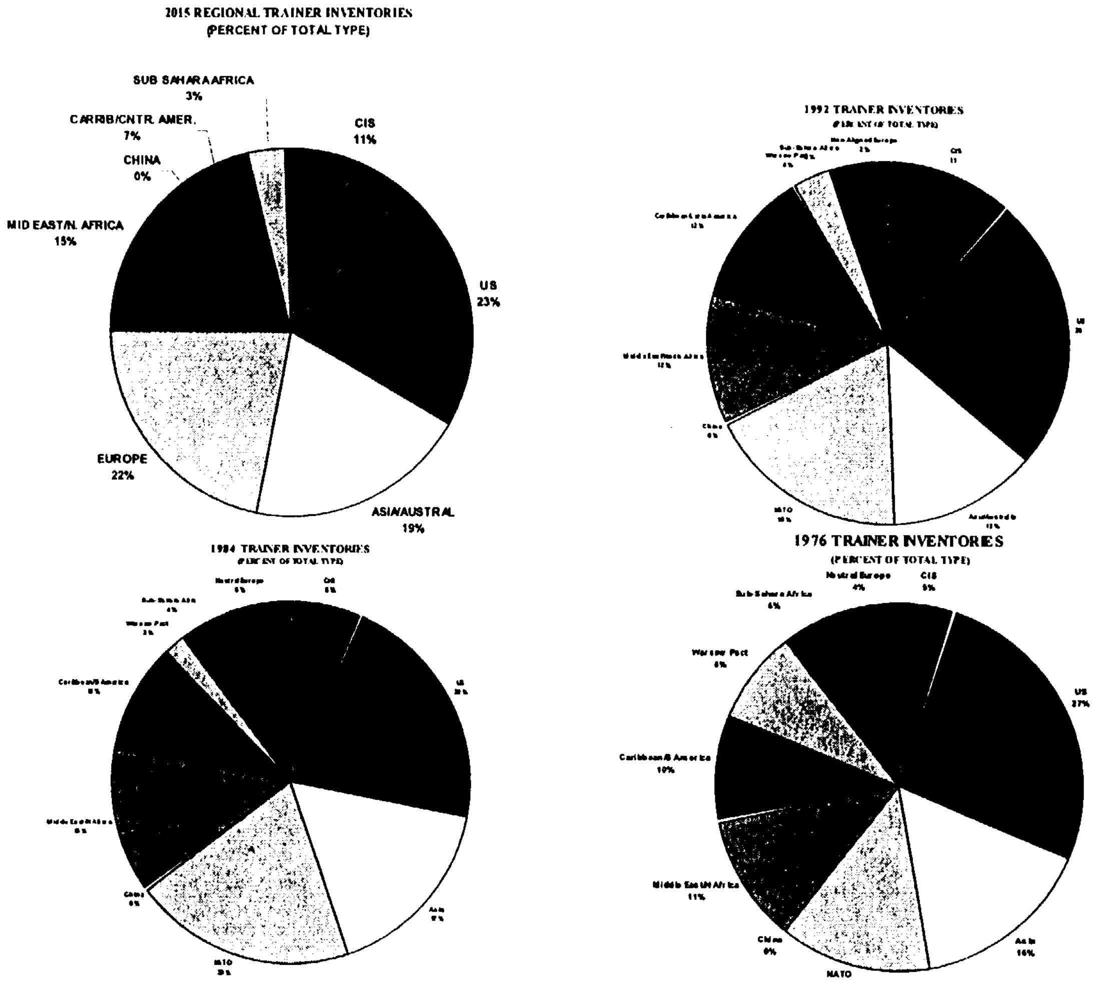
Appendix A Figure 1 Regional Fighter inventories for scenario years 1976, 1984 1992 and forecast year 2015



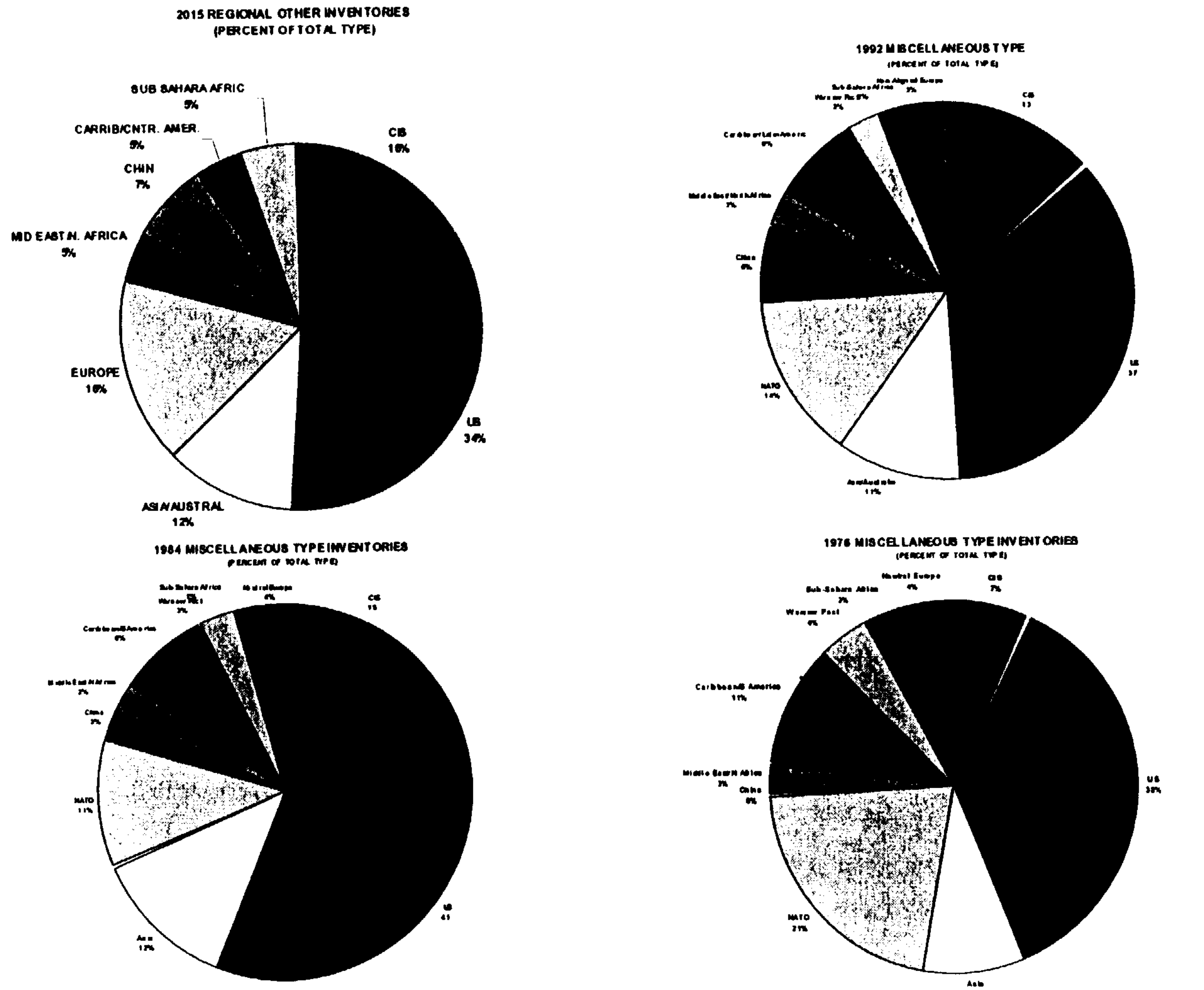
Appendix A Figure 2 Regional Transport inventories for scenario years 1976, 1984 1992 and forecast year 2015



Appendix A Figure 3 Regional Bomber inventories for scenario years 1976, 1984 1992 and forecast year 2015



Appendix A Figure 4 Regional Trainer inventories for scenario years 1976, 1984 1992 and forecast year 2015



Appendix A Figure 5 Regional Miscellaneous Other inventories for scenario years 1976, 1984 1992 and forecast year 2015

The emission indices in Appendix A Table 3, shown below, correspond to the generic military aircraft engine types previously identified and have incorporated new technology algorithms (Baughcum, Reference 2, 1996)

Engine	Altitude Band Upper Limit (KM)	Emission Indices (g/KG) NOX	CO	THC
E1	1	5.6	5.8	1.4
	6	7.2	6.3	1.2
	30	7.3	13.6	1.2
E2	1	34.4	3.8	0.2
	12	28.7	2.7	0.1
	30	16.2	6.3	0.5
E3	1	18.2	2.7	0.3
	10	22.8	5.1	0.5
	30	17.9	4.0	0.5
E4A	1	18.5	1.6	0.2
	8	14.0	4.2	0.3
	30	7.3	12.1	2.7
E4B	1	18.1	1.6	0.2
	8	13.6	4.5	0.3
	30	7.6	11.2	2.4
E5	1	15.6	1.0	0.1
	8	14.3	1.4	0.1
	10	11.3	3.2	0.2
	30	8.6	4.3	0.2
E6A	1	7.2	7.2	3.2
	10	8.7	4.7	0.8
	30	6.7	9.3	3.3
E6B	1	7.3	7.1	2.9
	10	9.2	3.2	0.5
	30	6.8	8.9	3.1
E7	1	7.8	2.1	0.4
	9	9.5	2.5	0.8
	30	7.4	2.4	0.4

Engine	Altitude Band Upper Limit (KM)	Emission Indices (g/KG) NOX	CO	THC
E8	1	5.2	20.5	1.1
	2	6.6	12.8	0.4
	7	8.9	10.8	1.0
	30	5.8	22.3	1.1
E9	1	5.8	15.3	3.1
	10	8.5	14.9	11.1
	30	8.0	6.6	3.1
E10	1	9.7	11.3	0.7
	10	13.5	10.5	1.8
	30	5.7	18.5	1.8
E11	1	9.1	1.8	0.4
	10	9.1	2.4	0.6
	13	6.2	14.6	6.7
	30	5.2	20.2	8.7
E12A	1	7.9	2.4	0.6
	7	7.6	3.8	1.6
	11	7.7	3.2	0.4
	30	5.7	4.9	0.4
E12B	1	8.3	2.2	0.5
	7	8.0	3.6	1.5
	30	6.0	4.7	1.2
E13	1	8.0	2.6	0.4
	4	6.1	3.6	0.4
	30	7.3	3.1	0.3
E14	1	3.9	15.2	10.8
	6	1.3	28.5	20.6
	30	1.8	15.2	12.6
E15	1	5.8	18.3	10.6
	2	7.2	11.1	5.0
	30	8.5	5.5	1.9

Appendix A Table 3 Exhaust emission indices of generic Military engine types

Details of charter and unreported domestic traffic data for the 1976 and 1984 scenario years are provided in Appendix A Table 4, Appendix A Table 5 and Appendix A Table 6. A synthesis of a wide variety of historic traffic data was used in creation of these notional traffic networks (Belet, Reference 38, 1991, Bucher, Reference 39,1984, CAA, Reference 40 , 1977, CTI, Reference 41, , 1991, DAC, Reference 42, 1976, FEASI, Reference 42, 1992, ICAO, Reference 44, 1991, Klee, Reference 45, , 1991, IATA, Reference 46, 1978, IATA, Reference 47, 1985, MDC, Reference 48, 1991, MDC, Reference 49, 1991, Statistics Canada, Reference 50, 1988, OAG, Reference 51, 1990., MDC,. Reference 52, 1990).

Appendix A Table 4 Charter missions for the 1976 and 1984 scenario year by region and aircraft type

REGION	ORIGIN	DESTIN.	TRIPS BY AIRCRAFT TYPE: WIDE BODY 2 ENG 1976	WIDE BODY 2 ENG 1984	WIDE BODY 3 ENG 1976	WIDE BODY 3 ENG 1984	WIDE BODY 4 ENG 1976	WIDE BODY 4 ENG 1984	NARROW BODY 2 ENG 1976	NARROW BODY 2 ENG 1984	NARROW BODY 3 ENG 1976	NARROW BODY 3 ENG 1984	NARROW BODY 4 ENG 1976	NARROW BODY 4 ENG 1984	TURBOPROP 2 ENG 1976	TURBOPROP 2 ENG 1984	TURBOPROP 4 ENG 1976	TURBOPROP 4 ENG 1984
N. AMERICA																		
	YYZ	YVR				207			1202	1836	207	713	350	380				
	YYZ	CDG			288	1368	298	494					2434	2417				
	YYZ	CUN			66	380	68	138			331	1263	557	673				
	YYZ	SDQ			52	299	54	108			260	992	438	528				
	YYZ	FLL				543			1490	4918	884	1911	5116	996				
	YYZ	LAS				181			497	1639	295	637	1705	332				
	YYZ	LAX				63			173	570	102	222	593	116				
	MIA	MEX							620	91	168	229	572	314				
	MIA	PTY							465	68	126	172	429	236				
	MIA	SAL							465	68	126	172	429	236				
	HNL	NRT			156	188							839	505				
	HNL	SEL			10	11							50	30				
	HNL	TPE			36	44							195	118				
	JFK	SDQ				904					1663	2232						
	MIA	SDQ							1663	2232								
	STL	SDQ											1312	1766				
	DFW	LAX							4651	4951	7611	2987	5297	5464				
	DFW	MIA							4651	4951	7611	2987	5297	5464				
	JFK	LAX			823	779	445	691	4651	4951	7611	2987	5297	5464				
	JFK	MIA			823	779	445	691										
	JFK	SJU			823	779	445	691										
	ORD	HNL			823	779	445	691										
	ORD	LAX							4651	4951	7611	2987	5297	5464				
	ORD	MIA							4651	4951	7611	2987	5297	5464				
	LAX	HNL			823	779	445	691										
	MIA	SJU															17137	13545
	JFK	MEX					95	118					558	346				

REGION	ORIGIN	DESTIN.	TRIPS BY AIRCRAFT TYPE WIDE BODY 2 ENG 1976	1984	3 ENG 1976	1984	4 ENG 1976	1984	NARROW BODY 2 ENG 1976	1984	3 ENG 1976	1984	4 ENG 1976	1984	TURBOPROP 2 ENG 1976	1984	4 ENG 1976	1984
	LAX	MEX					24	30					140	86				
	ORD	MEX					119	148					698	432				
S. AMERICA																		
	GIG	MIA				697		25					1574	222				
	GIG	REC							4525	225	92	1268						
	GIG	GRU													406	2518		
	BOG	MIA											647	728				
	BOG	LIM							682		100	1341						
	BOG	CCS							682		100	1341						
	BOG	CLO														3740	773	698
	EZE	MIA									485	2161						
	EZE	REC											346	263				
	EZE	GRU							168	357					678	354	329	
EUROPE																		
	LHR	BOS			166	146							489	428				
	LHR	BOS			99	87							292	255				
	LHR	LAX			67	59							197	173				
	LHR	MIA			44	38							129	113				
	LHR	JFK			642	564							1886	1653				
	LHR	SFO			44	38							129	113				
	LHR	SEA			44	38							129	113				
	CDG	BOS			172	151							506	443				
	CDG	ORD			102	90							300	263				
	CDG	LAX			70	62							206	180				
	CDG	MIA			47	41							137	120				
	CDG	JFK			665	585							1955	1713				
	CDG	SFO			47	41							137	120				
	CDG	SEA			47	41							137	120				

REGION	ORIGIN	DESTIN.	TRIPS BY AIRCRAFT TYPE WIDE BODY 2 ENG 1976	WIDE BODY 2 ENG 1984	WIDE BODY 3 ENG 1976	WIDE BODY 3 ENG 1984	WIDE BODY 4 ENG 1976	WIDE BODY 4 ENG 1984	NARROW BODY 2 ENG 1976	NARROW BODY 2 ENG 1984	NARROW BODY 3 ENG 1976	NARROW BODY 3 ENG 1984	NARROW BODY 4 ENG 1976	NARROW BODY 4 ENG 1984	TURBOPROP 2 ENG 1976	TURBOPROP 2 ENG 1984	TURBOPROP 4 ENG 1976	TURBOPROP 4 ENG 1984
	FRA	BOS			99	87							292	255				
	FRA	ORD			58	51							171	150				
	FRA	LAX			41	36							120	105				
	FRA	MIA			263	231							772	676				
	FRA	JFK			385	338							1132	992				
	FRA	SFO			263	231							772	676				
	FRA	SEA			263	231							772	676				
	CDG	SDQ			543	802	3112	5176										
	CDG	LHR	364	751	543	802			4736	5897	4593	2890	929	583				
	CDG	MRS													1317	1848	918	4030
	CDG	FCO	364	751					4736	5897	4593	2890	929	583				
	CDG	TUN	364	375	543	401			2368	2948	2296	1445	464	291				
	FRA	ATH	364	1877	543	2005			2368	14741	11481	7226	2322	1457				
	FRA	HAM													658	942	459	4015
	FRA	MAD	364	3002	543	3208			2368	23586	18370	11561	3715	2331				
	FRA	MUC													658	942	459	4015
	FRA	TUN	364	751	543	802			4736	5897	4593	2890	929	583				
	BEG	ATH							2517	3419		237	865	1741				
	BEG	BUD													5984			
	BEG	BUH													5984			
	BEG	IST							2517	3419		237	865	1741				
	BEG	LHR		849														
	BEG	PRG							2517	3419		237	865	1741			2018	3004
	BEG	MOW							1888	2564		178	649	1305			4037	6007
	BEG	WAW							1259	1710		119	432	870			2018	3004
	STO	ATH		235	73	236			3864	3430	973	923	1186	1073				
	STO	CPH													4601	1514	203	1490
	STO	FCO		392	122	394			6440	5717	1622	1538	1976	1788				
	STO	PMI		940	292	944			15455	13720	3893	3692	4743	4291				
	LHR	CDG		61	267	291		98	4490	3918		1005	1930	317			970	1042

			TRIPS BY AIRCRAFT TYPE															
			WIDE BODY						NARROW BODY						TURBOPROP			
REGION	ORIGIN	DESTIN.	2 ENG		3 ENG		4 ENG		2 ENG		3 ENG		4 ENG		2 ENG		4 ENG	
			1976	1984	1976	1984	1976	1984	1976	1984	1976	1984	1976	1984	1976	1984	1976	1984
	LHR	DUB														13627		
	LHR	FRA		255	1122	1224		411	18856	16454		4222	8108	1333			4075	4378
	LHR	FCO		170	748	816		274	12571	10969		2815	5405	888			2717	2919
	LHR	GVA		61	267	291		98	4490	3918		1005	1930	317			970	1042
	LHR	MAD		511	2245	2447		822	37713	32907		8445	16216	2665			8150	8756
	LHR	MOW		24	107	117		39	1796	1567		402	772	127			388	417
	LHR	STO		85	374	408		137	6285	5485		1407	2703	444			1358	1459
	LHR	TCI		49	214	233		78	3592	3134		804	1544	254			776	834
	LIS	FAO													188	1264		
	LIS	LHR							4300	3854	372	221	3751	1855				
	MAD	PMI		873	228										570	3079		
	MAD	TCI																
	PMI	CDG							1720	1542	149	88	1500	742				
	PMI	FRA							3440	3083	298	176	3001	1484				
	PMI	LHR							6020	5396	521	309	5251	2596				
	PMI	STO							1720	1542	149	88	1500	742				
AFRICA																		
	NBO	MBA													422	460		
	NBO	LHR											267	1106				
	NBO	ADD																
	NBO	LOS																
	CAI	ASW													5465	8590		2860
	CAI	GVA							910	1908	910	1908	910	1908				
	CAI	JED							910	1908	910	1908	910	1908				
	CAI	TUN							910	1908	910	1908	910	1908				
	JNB	CPT		97				100							3552	776		
	LOS	ROM											991	754				
	LOS	ACC													2908	1865	80	
	LOS	DKR							530	340	52							
	LOS	KIH							530	340	52							

REGION	ORIGIN	DESTIN.	TRIPS BY AIRCRAFT TYPE: WIDE BODY 2 ENG 1976	WIDE BODY 2 ENG 1984	WIDE BODY 3 ENG 1976	WIDE BODY 3 ENG 1984	WIDE BODY 4 ENG 1976	WIDE BODY 4 ENG 1984	NARROW BODY 2 ENG 1976	NARROW BODY 2 ENG 1984	NARROW BODY 3 ENG 1976	NARROW BODY 3 ENG 1984	NARROW BODY 4 ENG 1976	NARROW BODY 4 ENG 1984	TURBOPROP 2 ENG 1976	TURBOPROP 2 ENG 1984	TURBOPROP 4 ENG 1976	TURBOPROP 4 ENG 1984
	BGW	CDG		588	753	79		1314										
	BGW	DAM							1192	727	160	121	1236	992				
	BGW	RUH		588	753	79		1314	2385	1455	320	241	2473	1985		62		23
	BGW	THR							1192	727	160	121	1236	992				
ASIA																		
	NRT	OSA													123	406		
	NRT	LHR					121	463					4203	1072				
	NRT	HKG	767	63									4203	1072				
	NRT	BJS									746	629						
	MNL	NRT					154	646										
	MNL	GUM			38	129												
	MNL	SIN		70														
	MNL	HKG							165	68		96	83	64				
	MNL	CEB													17996	25006	10402	654
	BOM	LHR						62	979	119								
	BOM	SIN		156				62	979	119								
	BOM	DEL													143	109		
	AKL	PPT					87	299					181					
	AKL	SYD					29	100					61					
	PER	SYD		359														
	ADL	CBR													939	1239	193	
	MEL	CBR													939	1239	193	
	SYD	CBR													1252	1679	258	
	BNE	SYD							2963	1057								

Appendix A Table 5 Origins/Destinations used for Charter routes

ICAO	CITY	LAT	LON	ICAO	CITY	LAT	LON	ICAO	CITY	LAT	LON
ACC	ACCRA	6 N	0 W	DKR	DAKAR	15 N	18 W	PER	PERTH	32 S	116 E
ADD	ADDIS ABABA	9 N	39 E	DUB	DUBLIN	53 N	6 W	PMI	PALMA	40 N	3 E
ADL	ADELAIDE	35 S	139 E	FCO	ROME	42 N	12 E	PPT	PAPEETE	18 S	150 W
AKL	AUCKLAND	37 S	175 E	FLL	FT. LAUDERDALE	26 N	80 W	PRG	PRAGUE	50 N	14 E
ASW	ASWAN	24 N	33 E	FRA	FRANKFURT	50 N	9 E	PTY	PANAMA CITY	9 N	79 W
ATH	ATHENS	38 N	24 E	GRU	SAO PAULO	24 S	47 W	REC	RECIFE	8 S	35 W
BJS	BEIJING	40 N	117 E	GUM	GUAM	14 N	145 E	ROM	ROME	42 N	15 E
BNE	BRISBANE	27 S	153 E	HAM	HAMBURG	54 N	10 E	RUH	RIYADH	25 N	47 E
BUD	BUDAPEST	48 N	19 E	HKG	HONG KONG	22 N	114 E	SAL	SAN SALVADOR	14 N	89 W
BUH	BUCHAREST	45 N	26 E	IST	ISTANBUL	41 N	29 E	SEL	SEOUL	38 N	127 E
CBR	CANBERRA	35 S	149 E	JED	JEDDAH	22 N	39 E	SIN	SINGAPORE	1 N	104 E
CCS	CARACAS	11 N	67 W	LAS	LAS VEGAS	36 N	115 W	SJU	SAN JUAN	19 N	66 W
CDG	PARIS	49 N	3 E	LIM	LIMA	12 S	77 W	STL	ST. LOUIS	39 N	90 W
CEB	CEBU	10 N	123 E	LIS	LISBON	39 N	9 W	THR	TEHRAN	36 N	51 E
CLO	CALI	4 N	76 W	MBA	MOMBASA	4 S	37 E	TPE	TAIPEI	25 N	121 E
CPH	COPENHAGEN	56 N	13 E	MEL	MELBOURNE	38 S	145 E	TUN	TUNIS	37 N	10 E
CPT	CAPE TOWN	34 S	19 E	MOW	MOSCOW	56 N	37 E	WAW	WARSAW	52 N	21 E
CUN	CANCUN	21 N	87 W	MRS	MARSEILLE	43 N	5 E				
DAM	DAMASCUS	34 N	37 E	MUC	MUNICH	48 N	12 E				
DEL	DELHI	29 N	77 E	OSA	OSAKA	35 N	135 E				

SEGMENT	A/C TYPE	1976 ASK (x 10^9)	1984 ASK (x 10^9)	SEGMENT	A/C TYPE	1976 ASK (x 10^9)	1984 ASK (x 10^9)	SEGMENT	A/C TYPE	1976 ASK (x 10^9)	1984 ASK (x 10^9)	SEGMENT	A/C TYPE	1976 ASK (x 10^9)	1984 ASK (x 10^9)
IST-AZZ	S3	16.69	20.51	SKD-TAS	S3	0.07	0.09	DOK-VKO	S1	0.37	0.45	BUS-VKO	S2	0.34	0.42
BUD-GDN	S2	11.12	13.67	DME-UFA	S3	0.82	1.01	DME-ULY	S1	0.30	0.37	VKO-VSG	S3	0.34	0.42
CAN-YIN	S3	18.77	23.06	ODS-VKO	S3	0.79	0.98	LWO-SIP	S3	0.47	0.57	SVO-UCT	S2	0.27	0.34
KWE-PEK	S2	19.33	23.76	SIP-VKO	S1	2.00	2.46	AER-KBP	S3	0.50	0.62	DME-RTW	S1	0.25	0.30
HRB-KHG	S3	18.77	23.06	KBP-LED	S1	1.20	1.48	KHV-UUS	S3	0.29	0.35	MSQ-ODS	S2	0.19	0.23
LED-SVO	S2	1.07	1.31	HRK-VKO	S2	0.22	0.27	ALA-TAS	S1	0.52	0.64	IEV-OZH	S3	0.06	0.07
TBS-VKO	S3	2.10	2.58	TAS-UGC	S3	0.35	0.43	KBP-ROV	S3	0.27	0.33	ASB-MYP	S3	0.05	0.06
KBP-VKO	S3	0.72	0.89	DME-TAS	S1	4.34	5.34	BTK-KHV	S3	1.07	1.31	BAK-TBS	S3	0.05	0.06
RIX-SVO	S3	0.72	0.88	KBP-SIP	S3	0.39	0.48	IKT-OVB	S3	0.64	0.79	DYU-SKD	S3	0.03	0.04
MSQ-SVO	S2	0.37	0.45	DME-FRU	S3	1.70	2.09	KBP-KRR	S1	0.27	0.33	ALA-FRU	S3	0.02	0.03
DME-VOG	S1	0.72	0.89	DME-DYU	S3	1.69	2.07	KBP-TLL	S2	0.25	0.31	BAK-EVN	S2	0.10	0.13
EVN-VKO	S3	3.95	4.85	DME-OVB	S3	1.61	1.98	ODS-RIX	S3	0.56	0.69	SUI-TBS	S3	0.07	0.08
KIV-VKO	S3	1.11	1.37	SCW-SVO	S2	0.29	0.35	UUD-VKO	S3	1.91	2.34	FEG-TAS	S3	0.04	0.04
DME-IKT	S3	3.60	4.43	LED-MSQ	S2	0.20	0.25	KEJ-VKO	S3	1.29	1.59				
MMK-SVO	S3	1.25	1.54	ROV-VOG	S3	0.05	0.07	BAX-DME	S3	1.26	1.54	TOTAL		168.5	207.1
SVO-VNO	S1	0.14	0.18	ALA-DME	S1	4.22	5.19	DME-KGF	S3	1.04	1.28				
ROV-VKO	S3	0.80	0.98	DME-TJM	S3	1.08	1.33	DME-OMS	S3	0.96	1.17				
SVO-TLL	S2	0.37	0.46	LED-ODS	S3	0.86	1.05	IEV-ODS	S3	0.05	0.07				
AER-VKO	S1	2.80	3.44	EVN-SIP	S3	0.57	0.71	DME-HTA	S3	2.03	2.50				
BAK-DME	S3	1.62	1.99	LWO-VKO	S1	0.56	0.69	DME-NOZ	S3	1.34	1.64				
KRR-VKO	S3	0.98	1.21	ASF-DME	S2	0.36	0.45	ASB-DME	S3	1.06	1.31				
DME-KHV	S1	6.30	7.75	DME-REN	S2	0.35	0.44	DME-SGC	S3	0.92	1.13				
LED-MMK	S3	0.75	0.92	DME-KZN	S1	0.33	0.41	MCX-VKO	S3	0.68	0.84				
DME-SVX	S1	3.52	4.32	ARH-LED	S2	0.22	0.27	DME-PEE	S3	0.50	0.61				
MRV-VKO	S1	2.25	2.77	KBP-TBS	S3	0.82	1.01	BKA-MQF	S1	0.49	0.60				
SUI-VKO	S1	2.04	2.51	ARH-SVO	S2	0.29	0.35	DME-KUF	S3	0.36	0.44				

Appendix A Table 6 Unreported Domestic Traffic component network model passenger demand loads

Generic charter and unscheduled domestic traffic performance data is provided in the following tables. Appendix A Table 7 and Appendix A Table 8 provide both mission profile data and updated engine emission indices with incorporated new technology algorithms. The data correspond to both the generic aircraft previously reported and updated data sources (Ward, Reference 1, 1994, Airbus Industries, Reference 53, 1978, BCAG, Reference 54, 1967, BCAG, Reference 55, 1968, BCAG, Reference 56, 1970, BCAG, Reference 57, 1983, BCAG, Reference 58, 1983, DAC, Reference 59, 1974, DAC, Reference 60, 1972, DAC, Reference 61, 1942, DeHaviland, Reference 62, 1978, Fokker, Reference 63, 1978, IL-62, Reference 64, 1976,and Yak-42, Reference 65, 1977)

1984/1976 TYPICAL CHARTER MISSION PROFILE DATA

	Takeoff		Land		Cruise		
Aircraft Type	Climb (St. Mile)	Fuel (LB)	Descent (St. Mile)	Fuel (LB)	Altitude (Ft)	Speed ((MPH)	Fuel Burn (LB/Hr)
Wide Body							
2-Engine	104	7107	110	1974	33000	523	11588
3-Engine	202	12789	136	3018	37000	542	14440
4-Engine	140	17721	125	2864	37000	558	21294
Narrow Body							
2-Engine	110	3483	158	1604	33000	478	4892
3-Engine	168	6567	121	1725	35000	528	8130
4-Engine	139	9257	132	2271	35000	493	10378
Turboprop							
1-Engine	12	45	48	117	7000	156	295
2-Engine	50	800	42	195	20000	293	1525
4-Engine	216	5680	70	860	25000	365	5110
Rotor							
Turbine	2	10	2	10	3000	135	390
Piston	2	40	2	40	1000	135	1070

Appendix A Table 7 Mission profile data used for 1984/1976 Charter component missions

Engine	Altitude Band Upper Limit (KM)	Emission Indices (g/KG) NOX	CO	THC
C1	1	9.3	12.4	0.7
	9	14.1	4.6	0.3
	30	9.4	3.4	0.1
C2	1	10.4	4.6	0.7
	9	11.8	2.0	0.5
	30	7.9	3.0	0.7
C3	1	14.0	7.1	0.7
	9	19.9	2.5	0.2
	30	13.7	2.1	0.2
C4	1	13.0	10.2	2.3
	8	21.0	3.7	0.9
	30	11.8	2.3	0.6
C5	1	18.2	13.4	5.1
	8	26.7	4.9	2.2
	10	9.3	6.2	1.6
C6	1	24.8	21.6	8.1
	10	30.6	3.6	1.4
	30	12.5	3.7	0.6
C7	1	5.8	19.4	7.8
	9	8.6	7.6	3.1
	30	8.2	4.7	1.9
C8	1	5.6	17.5	5.1
	9	10.1	2.3	2
	30	8.2	16.1	9.8
C9	1	4.4	44.4	30.5
	5	4.4	44.4	30.5
C10	1	6	27.5	40.7
	5	6	27.5	40.7
S1	1	3.1	63.6	20.0
	9	5.9	21.5	3.1
	30	5.0	21.9	4.1
S2	1	3.0	81.6	65.8
	9	8.0	14.2	2.3
	30	6.7	19.1	3.0
S3	1	6.9	27.7	4.2
	9	13.6	22.4	0.9
	30	11.7	30.5	1.3

Appendix A Table 8 Exhaust emission indices of generic Charter and Unreported Domestic Traffic engine types

Details of general aviation traffic data all scenario years is provided in Appendix A Table 9,. A synthesis of a wide variety of historic traffic data was used (ICAO, References 12 through Reference 22). Review of GAMA data resulted in modification to equate total inventories to utilization. The modifications required to create equivalent inventories is shown in Appendix A Table 10 (GAMA, Reference 23 through 28, and FAA, Reference 29, 1995). Specific details of general aviation basing is described in Appendix A Table 11 and Appendix A Table 12.

Appendix A Table 9 General Aviation missions for the historic 1992,1984 and 1976 scenario years by region and type

	ANNUAL MISSIONS (1000)																	
	EXEC JET			TURBO PROP - 1 ENG			TURBO PROP - MULTI ENG			PISTON - 1 ENG			PISTON - MULTI ENG			ROTOR		
REGION	1976	1984	1992	1976	1984	1992	1976	1984	1992	1976	1984	1992	1976	1984	1992	1976	1984	1992
CANADA	16	22	24	10	8	10	60	60	200	3430	2136	2788	362	372	270	147	99	112
CARIBBEAN	2	4	2	0	0	0	2	8	8	28	98	76	6	30	18	1	7	6
CNTRL. AMER	4	26	62	0	0	6	4	32	46	424	1138	1392	100	266	178	13	40	31
ALASKA	40	56	44	0	2	10	92	90	52	934	856	750	184	206	132	27	45	47
US- CNTRL	58	82	60	0	4	14	124	130	70	1362	1250	1028	268	302	180	39	66	65
US-MID. ATLANTIC	156	226	154	0	10	34	366	356	180	3716	3406	2620	732	822	462	86	149	136
US-MIDWEST	184	264	178	0	12	40	432	418	210	4374	4010	3042	832	968	536	123	212	192
US-NEW ENGLAND	60	84	36	0	4	16	138	134	84	1400	1288	1218	276	310	214	30	32	58
US-NORTHWEST	22	30	90	0	6	22	186	180	108	1890	1734	1460	374	420	274	44	76	81
US-SOUTHEAST	168	242	194	0	12	44	394	382	228	3994	3662	3300	788	884	580	112	194	208
US-SOUTHWEST	199	286	161	0	14	36	465	452	190	4718	4327	2762	931	1044	485	133	229	174
US-WEST	246	354	266	0	16	60	576	558	312	5836	5350	4532	1050	1290	796	130	224	225
S. AMERICA -MID	6	20	52	0	64	46	12	50	98	546	1572	1202	120	420	332	9	33	32
S. AMERICA -NORTH	0	2	4	0	2	4	2	90	44	242	678	638	120	344	228	8	36	32
S. AMERICA -SOUTH	0	2	4	0	0	2	8	32	24	388	1102	736	60	190	112	7	23	16
EUROPE-CENTRAL	24	52	124	6	14	22	26	86	98	1962	3562	4562	244	360	304	60	162	296
EUROPE-EAST	4	12	12	0	0	0	4	10	24	244	622	724	34	46	54	12	32	73
EUROPE-NORTH	2	2	12	0	2	2	10	36	64	372	608	774	58	84	88	18	35	54
EUROPE-NORTHWEST	14	22	46	0	0	0	10	40	82	712	1406	1918	180	242	236	37	70	106
EUROPE-PENINSULA	0	0	0	0	0	0	2	4	22	192	290	370	30	46	52	8	11	26
AFRICA-EAST	4	4	4	0	0	0	6	6	8	120	106	82	28	32	20	5	8	6

	ANNUAL MISSIONS (1000)																	
	EXEC JET			TURBO PROP - 1 ENG			TURBO PROP - MULTI ENG			PISTON - 1 ENG			PISTON - MULTI ENG			ROTOR		
REGION	1976	1984	1992	1976	1984	1992	1976	1984	1992	1976	1984	1992	1976	1984	1992	1976	1984	1992
AFRICA-NORTH	2	2	2	0	0	2	2	10	10	60	74	62	16	12	6	1	3	2
AFRICA-SOUTH	2	6	4	0	2	2	4	14	14	514	456	342	122	130	90	14	18	12
AFRICA-WEST	2	4	4	0	0	0	2	4	4	80	70	54	18	22	14	3	5	4
MID. EAST	2	2	4	0	0	0	6	10	12	110	148	130	26	46	32	5	12	10
ASIA-NORTH	0	0	1	0	0	0	2	4	22	172	290	370	30	46	52	8	12	27
PACIFIC	0	0	0	0	0	0	0	2	6	10	30	48	2	10	12	1	2	4
ASIA-SOUTHEAST	2	8	8	0	0	0	20	52	64	46	74	124	40	54	30	18	45	56
ASIA-SOUTHWEST	0	0	0	0	0	0	0	6	18	106	118	140	22	32	28	16	12	21
AUSTRALIA	4	16	34	0	10	50	12	66	132	1492	2602	3368	238	238	238	39	36	173
TOTAL	**1223**	**1830**	**1586**	**16**	**182**	**422**	**2967**	**3322**	**2434**	**39474**	**43063**	**40612**	**7291**	**9268**	**6053**	**1154**	**1928**	**2285**

EFFECTIVE INVENTORY REDUCTION			
Aircraft Type	**1992**	**1984**	**1976**
Piston			
1-Engine	0.28	0.31	0.38
2-Engine	0.25	0.31	0.39
Executive Jet	0.39	0.63	0.60
Turboprop	0.73	1.20	0.85
Rotor	0.37	0.34	0.26

Appendix A Table 10 Effective operational inventory reduction following GAMA discussions and review of historical data

Appendix A Table 11General Aviation centroid mission origins

REGION	ORIGIN	REGION	ORIGIN	REGION	ORIGIN
CANADA		**US (cont.)**		**AFRICA**	
WEST	YVR			EAST	NBO
EAST	YYZ	SOUTHWEST	DFW	NORTH	CAI
CARIBBEAN	SDQ		IAH	SOUTH	JNB
CNTRL. AMER			MSY	WEST	LOS
NORTHERN	MEX		OKC	MID. EAST	BGW
SOUTHERN	MGA	WEST	LAX	**ASIA**	
UNITED STATES			PHX	NORTH	NRT
CENTRAL	MCI		SFO	PACIFIC	SUV
MID. ATLANTIC	JFK	ALASKA	ANC	SOUTHEAST	BKK
	WAS	**SOUTH AMERICA**			JKT
MIDWEST	ORD	CENTRAL	RIO		MNL
	DTW	NORTHERN	BOG	SOUTHWEST	BOM
	MSP	SOUTHERN	BUE	AUSTRALIA	SYD
NEW ENGLAND	BOS	**EUROPE**			
NORTHWEST	SEA	CENTRAL	GVA		
	DEN	EAST	BEG		
SOUTHEAST	MIA	NORTH	STO		
	ATL	NORTHWEST	LHR		
	CLT	PENINSULA	MAD		

Appendix A Table 12 Geographic definition of General Aviation centroids

ICAO	CITY	LAT	LON	ICAO	CITY	LAT	LON	ICAO	CITY	LAT	LON
ANC	ANCHORAGE	61 N	150 W	JNB	JOHANNESBURG	26 S	28 E	SDQ	SANTO DOMINGO	18 N	70 W
ATL	ATLANTA	33 N	84 W	LAX	LOS ANGELES	34 N	118 W	SEA	SEATTLE	47 N	122 W
BEG	BELGRADE	45 N	20 E	LHR	LONDON	52 N	0 W	SFO	SAN FRANCISCO	38 N	122 W
BGW	BAGHDAD	33 N	44 E	LOS	LAGOS	7 N	3 E	STO	STOCKHOLM	60 N	18 E
BKK	BANGKOK	14 N	101 E	MAD	MADRID	41 N	4 W	SUV	SUVA	18 S	179 E
BOG	BOGATA	5 N	79 W	MCI	KANSAS CITY	39 N	95 W	SYD	SYDNEY	34 S	151 E
BOM	BOMBAY	19 N	73 E	MEX	MEXICO CITY	19 N	73 W	WAS	WASHINGTON	39 N	79 W
BOS	BOSTON	42 N	71 W	MGA	MANAGUA	12 N	27 W	YVR	VANCOUVER	49 N	123 W
BUE	BUENES AIRES	35 S	59 W	MIA	MIAMI	26 N	80 W	YYZ	TORONTO	44 N	80 W
CAI	CAIRO	30 N	31 E	MNL	MANILA	15 N	121 E				
CLT	CHARLOTTE	35 N	81 W	MSP	MINNEAPOLIS	45 N	93 W				
DEN	DENVER	40 N	105 W	MSY	NEW ORLEANS	30 N	90 W				
DFW	DALLAS	33 N	97 W	NBO	NAIROBI	1 S	37 E				
DTW	DETROIT	42 N	83 W	NRT	TOKYO	36 N	140 E				
GVA	GENEVA	46 N	6 E	OKC	OKLAHOMA CITY	35 N	98 W				
IAH	HOUSTON	30 N	95 W	ORD	CHICAGO	42 N	88 W				
JFK	NEW YORK	41 N	74 W	PHX	PHOENIX	33 N	112 W				
JKT	JAKARTA	6 S	107 E	RIO	RIO DE JANEIRO	23 S	43 W				

Performance data for generic general aviation is provided in Appendix A Table 13 was used in developing basic mission profiles for allocating fuel usage and emissions (Fokker, Reference 63, 1978, Yak-42, Reference 65, 1977, Cessna, Reference 66, 1977, and Gates, Reference 68, 1991). Engine emission indices for the generic general aviation engines is shown in Appendix A Table 14 using the technology algorithms previously identified and operational characteristics of piston engines (Pace, Reference 6, 1977, Sears, Reference 7, 1978, ICAO, Reference 8, 1989, Teledyne Continental Motors, Reference 9, 1976).

1984/1976 TYPICAL GENERAL AVIATION MISSION PROFILE DATA

	Takeoff		Land		Cruise		
Aircraft Type	Climb (St. Mile)	Fuel (LB)	Descent (St. Mile)	Fuel (LB)	Altitude (Ft)	Speed ((MPH)	Fuel Burn (LB/Hr)
Executive Jet							
2-Engine	93	1264	62	622	43000	472	1474
Turboprop							
1-Engine	12	45	48	117	7000	156	295
2-Engine	7	60	48	156	7000	173	400
Piston							
1-Engine	31	29	20	10	8000	132	71
2-Engine	9	38	7	30	9000	170	430
Rotor							
Turbine	2	10	2	10	3000	135	390
Piston	2	40	2	40	1000	135	1070

Appendix A Table 13 Mission profile data used for General Aviation component missions

Engine	Altitude Band Upper Limit (KM)	Emission Indices (g/KG) NOX	CO	THC
G!	1	5.3	27.0	6.5
	10	11.0	1.2	1.2
	30	9.9	1.7	0.9
G2	1	4.2	50.0	28.0
	2	5.1	37.1	16.4
	30	6.1	26.1	2.4
G3	1	3.8	51.5	3.8
	2	4.7	45.1	4.7
	30	5.2	29.6	5.2
G4	1	6.7	864.7	15.4
	30	11.7	243.6	5.9
G5	1	7.1	905.6	19.2
	30	41.6	289.9	6.6
G6	1	4.4	44.4	30.5
	5	4.4	44.4	30.5
G7	1	6	27.5	40.7
	5	6	27.5	40.7

Appendix A Table 14 Exhaust emission indices of generic General Aviation engine types

The following tables present initially delivered assessments of emission inventories performed prior to introduction of the new technology algorithms. They are presented here only for use as a historical record.

Appendix A Table 15 Initial submittal 2015 Military

Alt. Band (KM)	FUEL Kilograms (x10^9)	FUEL Cum. Pct.	NOX Grams (x10^9)	Cum. NOX	CO Grams (x10^9)	Cum. CO	THC Grams (x10^9)	Cum. THC	Emission Index (EI) NOX	Emission Index (EI) CO	Emission Index (EI) THC
1	2.29	11.1%	29.62	14.8%	20.07	3.7%	3.70	1.4%	13.0	8.8	1.6
2	1.35	17.7%	9.50	19.5%	17.53	6.9%	1.36	1.9%	7.0	13.0	1.0
3	0.69	21.0%	5.72	22.4%	7.28	8.2%	1.45	2.5%	8.3	10.6	2.1
4	0.53	23.6%	4.22	24.5%	6.53	9.4%	1.13	2.9%	7.9	12.3	2.1
5	0.35	25.3%	3.00	26.0%	5.91	10.5%	0.90	3.3%	8.7	17.1	2.6
6	0.34	26.9%	3.11	27.5%	6.08	11.6%	0.93	3.6%	9.1	17.7	2.7
7	1.14	32.5%	6.89	31.0%	24.22	16.0%	1.27	4.1%	6.0	21.3	1.1
8	1.53	39.9%	11.91	36.9%	33.25	22.1%	3.93	5.6%	7.8	21.8	2.6
9	0.92	44.4%	9.50	41.7%	23.51	26.4%	6.00	7.9%	10.3	25.5	6.5
10	2.11	54.6%	24.03	53.7%	59.66	37.3%	12.19	12.6%	11.4	28.3	5.8
11	3.06	69.5%	32.40	69.8%	98.28	55.3%	48.57	31.2%	10.6	32.1	15.9
12	3.18	85.0%	27.90	83.8%	125.96	78.3%	92.25	66.6%	8.8	39.6	29.0
13	2.10	95.1%	21.64	94.6%	75.58	92.1%	48.25	85.1%	10.3	36.0	23.0
14	0.62	98.1%	7.22	98.2%	22.47	96.2%	19.50	92.6%	11.7	36.4	31.6
15	0.22	99.2%	1.66	99.0%	15.64	99.1%	15.40	98.5%	7.7	72.4	71.3
16	0.17	100.0%	2.03	100.0%	4.86	100.0%	3.87	100.0%	12.3	29.4	23.4
Total	20.58		200.34		546.84		260.73				

Appendix A Table 16 Initial submittal 1992 Military

	FUEL		NOX		CO		THC		Emission Index (EI)		
Alt. Band (KM)	Kilograms (x10^9)	Cum. Fuel	Grams (x10^9)	Cum. NOX	Grams (x10^9)	Cum. CO	Grams (x10^9)	Cum. THC	NOX	CO	THC
1	3.30	13.0%	47.27	18.3%	25.64	3.9%	5.05	1.7%	14.3	7.8	1.5
2	1.56	19.1%	11.23	22.7%	20.24	6.9%	1.65	2.2%	7.2	12.9	1.1
3	0.81	22.3%	6.88	25.3%	8.89	8.3%	1.72	2.8%	8.4	10.9	2.1
4	0.66	24.9%	5.43	27.4%	8.19	9.5%	1.41	3.3%	8.2	12.3	2.1
5	0.45	26.7%	4.05	29.0%	7.49	10.7%	1.15	3.6%	9.0	16.7	2.6
6	0.45	28.4%	4.21	30.6%	7.75	11.8%	1.19	4.0%	9.4	17.3	2.7
7	1.48	34.2%	9.58	34.4%	30.42	16.4%	1.65	4.6%	6.4	20.5	1.1
8	1.85	41.5%	15.02	40.2%	38.25	22.2%	4.52	6.1%	8.1	20.7	2.4
9	0.99	45.4%	9.99	44.1%	28.36	26.5%	8.58	8.9%	10.1	28.7	8.7
10	2.76	56.2%	31.53	56.3%	78.29	38.4%	16.10	14.2%	11.4	28.3	5.8
11	3.84	71.3%	41.15	72.2%	127.00	57.6%	59.91	34.1%	10.7	33.1	15.6
12	3.47	84.9%	30.65	84.1%	133.58	77.8%	93.10	64.9%	8.8	38.5	26.8
13	2.41	94.4%	25.63	94.0%	83.46	90.5%	48.97	81.1%	10.6	34.6	20.3
14	0.86	97.8%	9.81	97.8%	32.61	95.4%	28.67	90.6%	11.5	38.1	33.5
15	0.33	99.0%	2.57	98.8%	23.14	98.9%	22.73	98.1%	7.8	70.7	69.4
16	0.24	100.0%	3.00	100.0%	7.15	100.0%	5.69	100.0%	12.3	29.3	23.4
Total	25.47		257.97		660.45		302.09				

Appendix A Table 17 Initial submittal 1984 Military

Alt. Band (KM)	FUEL Kilograms (x10^9)	FUEL Cum. Pct.	NOX Grams (x10^9)	Cum. NOX	CO Grams (x10^9)	Cum. CO	THC Grams (x10^9)	Cum. THC	Emission Index (EI) NOX	EI CO	EI THC
1	3.98	13.6%	57.87	19.2%	31.92	4.3%	6.21	2.1%	14.5	8.0	1.6
2	2.12	20.9%	18.47	25.3%	23.38	7.4%	1.81	2.7%	8.7	11.0	0.9
3	0.91	24.0%	8.19	28.0%	10.57	8.8%	1.87	3.3%	9.0	11.6	2.1
4	0.90	27.0%	8.64	30.8%	10.21	10.2%	1.66	3.9%	9.6	11.4	1.8
5	0.53	28.9%	4.88	32.5%	9.50	11.5%	1.36	4.4%	9.2	17.9	2.6
6	0.53	30.7%	5.09	34.1%	9.85	12.8%	1.41	4.8%	9.6	18.5	2.6
7	1.68	36.4%	10.11	37.5%	41.26	18.3%	1.92	5.5%	6.0	24.6	1.1
8	2.24	44.1%	21.36	44.6%	41.20	23.8%	4.85	7.1%	9.5	18.4	2.2
9	0.67	46.4%	7.78	47.1%	15.56	25.9%	5.38	8.9%	11.6	23.3	8.0
10	3.49	58.3%	37.82	59.7%	110.98	40.8%	21.63	16.2%	10.8	31.8	6.2
11	4.46	73.6%	47.47	75.4%	153.08	61.3%	61.71	37.0%	10.6	34.3	13.8
12	3.92	87.0%	36.92	87.6%	142.12	80.3%	93.11	68.4%	9.4	36.3	23.8
13	2.79	96.5%	28.29	97.0%	99.31	93.6%	51.11	85.6%	10.1	35.6	18.3
14	0.64	98.7%	6.28	99.0%	25.37	97.0%	21.48	92.9%	9.8	39.4	33.3
15	0.21	99.4%	1.26	99.4%	16.97	99.3%	16.87	98.6%	6.1	82.2	81.7
16	0.17	100.0%	1.67	100.0%	5.51	100.0%	4.26	100.0%	9.9	32.8	25.3
Total	29.25		302.12		746.80		296.63				

Appendix A Table 18 Initial submittal 1976 Military

	FUEL		NOX		CO		THC		Emission Index (EI)		
Alt. Band (KM)	Kilograms (x10^9)	Cum. Fuel	Grams (x10^9)	Cum. NOX	Grams (x10^9)	Cum. CO	Grams (x10^9)	Cum. THC	NOX	CO	THC
1	4.75	13.6%	55.21	17.4%	51.14	5.5%	8.06	2.6%	11.6	10.8	1.7
2	3.35	23.1%	24.39	25.1%	43.91	10.2%	2.77	3.5%	7.3	13.1	0.8
3	1.41	27.1%	13.81	29.4%	17.76	12.0%	2.50	4.3%	9.8	12.6	1.8
4	1.42	31.2%	14.47	34.0%	17.67	13.9%	2.29	5.0%	10.2	12.4	1.6
5	0.81	33.5%	6.43	36.0%	16.89	15.7%	1.93	5.6%	8.0	20.9	2.4
6	0.81	35.8%	6.70	38.1%	17.50	17.6%	2.00	6.3%	8.3	21.7	2.5
7	2.63	43.3%	12.34	42.0%	102.02	28.5%	3.23	7.3%	4.7	38.8	1.2
8	3.29	52.7%	28.24	50.9%	76.41	36.7%	8.27	10.0%	8.6	23.2	2.5
9	0.78	54.9%	7.43	53.3%	21.53	39.0%	7.68	12.4%	9.5	27.4	9.8
10	3.13	63.9%	30.56	62.9%	108.60	50.6%	21.89	19.5%	9.8	34.6	7.0
11	4.55	76.9%	42.67	76.3%	166.16	68.3%	67.84	41.3%	9.4	36.5	14.9
12	4.27	89.0%	38.73	88.6%	153.07	84.7%	96.58	72.3%	9.1	35.8	22.6
13	2.88	97.2%	27.49	97.2%	103.94	95.8%	52.78	89.3%	9.6	36.1	18.3
14	0.62	99.0%	6.10	99.1%	21.49	98.1%	16.94	94.7%	9.8	34.6	27.3
15	0.17	99.5%	1.09	99.5%	13.32	99.5%	13.09	98.9%	6.3	77.4	76.0
16	0.17	100.0%	1.64	100.0%	4.91	100.0%	3.41	100.0%	9.5	28.6	19.8
Total	35.06		317.29		936.33		311.25				

Appendix A Table 19 Initial submittal 2015 Charter

	FUEL		NOX		CO		THC		Emission Index (EI)		
Alt. Band (KM)	Kilograms (x10^9)	Cum. Fuel	Grams (x10^9)	Cum. NOX	Grams (x10^9)	Cum. CO	Grams (x10^9)	Cum. THC	NOX	CO	THC
1	0.62	4.6%	4.07	2.4%	10.22	10.9%	1.16	9.8%	6.5	16.4	1.9
2	0.62	9.3%	7.08	6.5%	1.70	12.7%	0.13	10.9%	11.3	2.7	0.2
3	0.62	13.9%	7.26	10.8%	1.76	14.5%	0.14	12.0%	11.6	2.8	0.2
4	0.62	18.5%	7.65	15.2%	1.82	16.5%	0.14	13.2%	12.3	2.9	0.2
5	0.69	23.7%	8.77	20.3%	2.17	18.8%	0.16	14.6%	12.6	3.1	0.2
6	0.59	28.0%	8.00	25.0%	1.83	20.7%	0.15	15.8%	13.6	3.1	0.3
7	0.59	32.4%	8.32	29.9%	1.90	22.7%	0.15	17.1%	14.1	3.2	0.3
8	0.59	36.7%	8.65	34.9%	1.96	24.8%	0.16	18.5%	14.8	3.4	0.3
9	0.58	41.1%	9.00	40.2%	2.03	27.0%	0.17	19.9%	15.4	3.5	0.3
10	4.20	72.2%	51.23	70.1%	39.29	68.7%	3.90	52.8%	12.2	9.3	0.9
11	2.90	93.7%	39.82	93.4%	22.76	92.9%	4.33	89.3%	13.7	7.9	1.5
12	0.85	100.0%	11.34	100.0%	6.67	100.0%	1.27	100.0%	13.3	7.8	1.5
Total	13.49		171.20		94.14		11.85				

Appendix A Table 20 Initial submittal 1992 Charter

Alt. Band (KM)	FUEL Kilograms (x10^9)	Cum. Fuel	NOX Grams (x10^9)	Cum. NOX	CO Grams (x10^9)	Cum. CO	THC Grams (x10^9)	Cum. THC	Emission Index (EI) NOX	CO	THC
1	0.29	4.5%	1.85	3.4%	4.84	9.6%	0.52	8.4%	6.4	16.6	1.8
2	0.29	8.9%	3.02	8.9%	0.84	11.3%	0.07	9.4%	10.4	2.9	0.2
3	0.29	13.4%	3.01	14.3%	0.88	13.0%	0.07	10.5%	10.3	3.0	0.2
4	0.29	17.8%	3.03	19.9%	0.93	14.9%	0.07	11.7%	10.4	3.2	0.2
5	0.32	22.7%	3.25	25.8%	1.10	17.1%	0.08	13.0%	10.1	3.4	0.3
6	0.28	26.9%	2.80	30.9%	0.97	19.0%	0.08	14.3%	10.1	3.5	0.3
7	0.28	31.1%	2.73	35.9%	1.02	21.0%	0.08	15.6%	9.9	3.7	0.3
8	0.27	35.3%	2.66	40.7%	1.07	23.1%	0.09	17.0%	9.7	3.9	0.3
9	0.27	39.5%	2.58	45.4%	1.13	25.4%	0.09	18.5%	9.4	4.1	0.3
10	2.10	71.6%	15.47	73.6%	21.98	69.0%	2.10	52.1%	7.4	10.5	1.0
11	1.44	93.6%	11.29	94.1%	11.88	92.7%	2.28	88.6%	7.8	8.3	1.6
12	0.42	100.0%	3.21	100.0%	3.70	100.0%	0.71	100.0%	7.6	8.8	1.7
Total	6.55		54.90		50.33		6.24				

Appendix A Table 21 Initial submittal 1984 Charter

Alt. Band (KM)	FUEL Kilograms (x10^9)	Cum. Fuel	NOX Grams (x10^9)	Cum. NOX	CO Grams (x10^9)	Cum. CO	THC Grams (x10^9)	Cum. THC	Emission Index (EI) NOX	CO	THC
1	0.38	4.1%	2.63	2.2%	5.63	8.0%	0.92	9.3%	7.0	15.0	2.5
2	0.30	7.4%	3.66	5.2%	0.73	9.0%	0.08	10.1%	12.1	2.4	0.3
3	0.28	10.4%	3.49	8.1%	0.67	9.9%	0.08	10.9%	12.5	2.4	0.3
4	0.28	13.5%	3.72	11.1%	0.70	10.9%	0.08	11.7%	13.2	2.5	0.3
5	0.28	16.5%	3.91	14.3%	0.73	12.0%	0.08	12.6%	13.9	2.6	0.3
6	0.28	19.6%	4.07	17.7%	0.75	13.0%	0.09	13.5%	14.5	2.7	0.3
7	0.31	23.0%	4.60	21.5%	0.95	14.4%	0.18	15.3%	14.7	3.0	0.6
8	0.42	27.6%	5.81	26.2%	1.57	16.6%	0.13	16.6%	13.7	3.7	0.3
9	0.24	30.2%	4.00	29.5%	0.73	17.6%	0.08	17.4%	17.0	3.1	0.3
10	0.70	37.8%	8.72	36.7%	6.16	26.4%	0.46	22.0%	12.5	8.8	0.7
11	3.80	79.2%	55.92	82.8%	22.70	58.5%	2.77	49.7%	14.7	6.0	0.7
12	1.91	100.0%	20.94	100.0%	29.33	100.0%	5.01	100.0%	11.0	15.3	2.6
Total	9.18		121.47		70.63		9.97				

Appendix A Table 22 Initial submittal 1976 Charter

	FUEL		NOX		CO		THC		Emission Index (EI)		
Alt. Band (KM)	Kilograms (x10^9)	Cum. Fuel	Grams (x10^9)	Cum. NOX	Grams (x10^9)	Cum. CO	Grams (x10^9)	Cum. THC	NOX	CO	THC
1	0.35	4.2%	3.47	7.4%	7.01	15.8%	1.27	22.2%	10.0	20.1	3.6
2	0.32	8.1%	3.63	15.0%	0.85	17.7%	0.09	23.8%	11.2	2.6	0.3
3	0.32	12.0%	2.53	20.4%	0.60	19.0%	0.06	24.9%	7.8	1.9	0.2
4	0.32	15.9%	2.52	25.7%	0.63	20.4%	0.06	26.0%	7.8	1.9	0.2
5	0.32	19.8%	2.50	31.0%	0.67	21.9%	0.07	27.2%	7.7	2.1	0.2
6	0.32	23.7%	2.45	36.2%	0.70	23.5%	0.07	28.4%	7.5	2.2	0.2
7	0.34	27.8%	2.46	41.4%	0.86	25.4%	0.12	30.6%	7.2	2.5	0.4
8	0.51	33.9%	2.62	47.0%	1.33	28.4%	0.12	32.7%	5.1	2.6	0.2
9	0.28	37.3%	1.99	51.2%	0.77	30.2%	0.07	33.9%	7.1	2.8	0.2
10	0.79	46.7%	4.19	60.1%	6.17	44.0%	0.39	40.8%	5.3	7.9	0.5
11	3.21	85.2%	15.22	92.3%	13.75	74.9%	1.28	63.1%	4.7	4.3	0.4
12	1.23	100.0%	3.63	100.0%	11.18	100.0%	2.11	100.0%	3.0	9.1	1.7
Total	8.33		47.22		44.53		5.72				

Appendix A Table 23 Initial submittal 2015 Unreported Domestic Traffic

	FUEL		NOX		CO		THC		Emission Index (EI)		
Alt. Band (KM)	Kilograms (x10^9)	Cum. Fuel	Grams (x10^9)	Cum. NOX	Grams (x10^9)	Cum. CO	Grams (x10^9)	Cum. THC	NOX	CO	THC
1	0.15	1.0%	0.83	0.6%	2.74	1.2%	0.98	1.7%	5.4	17.9	6.4
2	0.15	1.9%	1.37	1.5%	0.68	1.5%	0.17	2.0%	8.9	4.5	1.1
3	0.15	2.9%	1.40	2.5%	0.70	1.9%	0.18	2.3%	9.2	4.6	1.2
4	0.15	3.9%	1.47	3.5%	0.73	2.2%	0.18	2.6%	9.7	4.8	1.2
5	0.15	4.8%	1.54	4.6%	0.75	2.5%	0.19	2.9%	10.2	5.0	1.2
6	0.17	5.9%	1.82	5.9%	0.86	2.9%	0.21	3.3%	10.7	5.1	1.2
7	0.17	7.0%	1.85	7.2%	0.89	3.3%	0.22	3.6%	11.0	5.3	1.3
8	0.14	7.8%	1.54	8.3%	0.76	3.7%	0.19	4.0%	11.4	5.6	1.4
9	0.13	8.7%	1.61	9.4%	0.79	4.0%	0.20	4.3%	11.9	5.8	1.5
10	0.92	14.5%	12.19	17.9%	7.03	7.2%	2.32	8.2%	13.3	7.6	2.5
11	11.27	85.9%	82.71	75.8%	178.73	87.6%	51.25	95.6%	7.3	15.9	4.5
12	1.52	95.5%	23.54	92.3%	18.84	96.0%	1.76	98.6%	15.5	12.4	1.2
13	0.71	100.0%	10.99	100.0%	8.78	100.0%	0.82	100.0%	15.5	12.4	1.2
Total	15.79		142.84		222.30		58.66				

Appendix A Table 24 Initial submittal 1992 Unreported Domestic Traffic

	FUEL		NOX		CO		THC		Emission Index (EI)		
Alt. Band (KM)	Kilograms (x10^9)	Cum. Fuel	Grams (x10^9)	Cum. NOX	Grams (x10^9)	Cum. CO	Grams (x10^9)	Cum. THC	NOX	CO	THC
1	0.09	1.0%	0.45	1.0%	1.54	1.1%	0.55	1.4%	5.3	18.1	6.5
2	0.09	1.9%	0.72	2.6%	0.39	1.3%	0.10	1.7%	8.5	4.6	1.1
3	0.08	2.9%	0.72	4.1%	0.41	1.6%	0.10	2.0%	8.5	4.8	1.2
4	0.08	3.9%	0.72	5.7%	0.43	1.9%	0.11	2.2%	8.5	5.1	1.3
5	0.08	4.9%	0.71	7.2%	0.45	2.2%	0.11	2.5%	8.4	5.3	1.3
6	0.08	5.8%	0.70	8.8%	0.48	2.5%	0.12	2.8%	8.2	5.6	1.4
7	0.09	6.9%	0.73	10.4%	0.54	2.9%	0.13	3.2%	8.0	6.0	1.5
8	0.08	7.7%	0.59	11.6%	0.48	3.2%	0.12	3.5%	7.8	6.3	1.6
9	0.07	8.6%	0.57	12.9%	0.50	3.6%	0.13	3.8%	7.6	6.7	1.7
10	0.51	14.5%	4.03	21.6%	4.64	6.7%	1.53	7.8%	7.8	9.0	3.0
11	6.24	85.8%	25.41	76.9%	117.33	86.6%	33.66	95.2%	4.1	18.8	5.4
12	0.85	95.5%	7.24	92.7%	13.22	95.5%	1.25	98.4%	8.5	15.6	1.5
13	0.39	100.0%	3.35	100.0%	6.54	100.0%	0.61	100.0%	8.6	16.7	1.6
Total	8.74		45.94		146.95		38.51				

Appendix A Table 25 Initial submittal 1984 Unreported Domestic Traffic

	FUEL		NOX		CO		THC		Emission Index (EI)		
Alt. Band (KM)	Kilograms (x10^9)	Cum. Fuel	Grams (x10^9)	Cum. NOX	Grams (x10^9)	Cum. CO	Grams (x10^9)	Cum. THC	NOX	CO	THC
1	0.07	1.0%	0.38	0.6%	1.27	1.2%	0.45	1.7%	5.4	17.9	6.4
2	0.07	1.9%	0.63	1.5%	0.32	1.5%	0.08	2.0%	8.9	4.5	1.1
3	0.07	2.9%	0.65	2.5%	0.33	1.9%	0.08	2.3%	9.1	4.6	1.2
4	0.07	3.9%	0.68	3.5%	0.34	2.2%	0.08	2.6%	9.6	4.8	1.2
5	0.07	4.9%	0.72	4.6%	0.35	2.5%	0.09	2.9%	10.1	5.0	1.2
6	0.07	5.8%	0.75	5.8%	0.36	2.9%	0.09	3.2%	10.6	5.2	1.3
7	0.08	6.9%	0.84	7.0%	0.41	3.3%	0.10	3.6%	11.0	5.4	1.3
8	0.06	7.7%	0.72	8.1%	0.35	3.6%	0.09	3.9%	11.4	5.6	1.4
9	0.06	8.6%	0.74	9.2%	0.37	4.0%	0.09	4.3%	11.9	5.8	1.5
10	0.43	14.5%	5.66	17.8%	3.32	7.2%	1.09	8.3%	13.2	7.7	2.5
11	5.22	85.8%	38.43	75.8%	82.56	87.6%	23.68	95.6%	7.4	15.8	4.5
12	0.71	95.5%	10.95	92.3%	8.74	96.1%	0.83	98.6%	15.5	12.3	1.2
13	0.33	100.0%	5.07	100.0%	4.06	100.0%	0.38	100.0%	15.5	12.4	1.2
Total	7.31		66.22		102.78		27.14				

Appendix A Table 26 Initial submittal 1976 Unreported Domestic Traffic

Alt. Band (KM)	FUEL Kilograms (x10^9)	Cum. Fuel	NOX Grams (x10^9)	Cum. NOX	CO Grams (x10^9)	Cum. CO	THC Grams (x10^9)	Cum. THC	Emission Index (EI) NOX	CO	THC
1	0.06	1.0%	0.31	0.6%	1.04	1.2%	0.37	1.7%	5.4	17.9	6.4
2	0.06	1.9%	0.51	1.5%	0.26	1.5%	0.06	2.0%	8.9	4.5	1.1
3	0.06	2.9%	0.53	2.5%	0.27	1.9%	0.07	2.3%	9.1	4.6	1.2
4	0.06	3.9%	0.56	3.5%	0.28	2.2%	0.07	2.6%	9.6	4.8	1.2
5	0.06	4.9%	0.58	4.6%	0.29	2.5%	0.07	2.9%	10.1	5.0	1.2
6	0.06	5.8%	0.61	5.8%	0.30	2.9%	0.07	3.2%	10.6	5.2	1.3
7	0.06	6.9%	0.68	7.0%	0.33	3.3%	0.08	3.6%	11.0	5.4	1.3
8	0.05	7.7%	0.58	8.1%	0.29	3.6%	0.07	3.9%	11.4	5.6	1.4
9	0.05	8.6%	0.61	9.2%	0.30	4.0%	0.08	4.3%	11.9	5.8	1.5
10	0.35	14.5%	4.61	17.8%	2.70	7.2%	0.89	8.3%	13.2	7.7	2.5
11	4.24	85.8%	31.27	75.8%	67.22	87.6%	19.27	95.6%	7.4	15.8	4.5
12	0.58	95.5%	8.91	92.3%	7.11	96.1%	0.67	98.6%	15.5	12.4	1.2
13	0.27	100.0%	4.13	100.0%	3.30	100.0%	0.31	100.0%	15.5	12.4	1.2
Total	5.95		53.88		83.68		22.08				

Appendix A Table 27 Initial submittal 2015 General Aviation

	FUEL		NOX		CO		THC		Emission Index (EI)		
Alt. Band (KM)	Kilograms (x10^9)	Cum. Fuel	Grams (x10^9)	Cum. NOX	Grams (x10^9)	Cum. CO	Grams (x10^9)	Cum. THC	NOX	CO	THC
1	3.23	20.8%	13.38	12.7%	1246.62	22.4%	79.52	0.56	4.1	385.5	24.6
2	2.37	36.1%	11.42	23.5%	1305.08	45.9%	29.34	0.76	4.8	550.0	12.4
3	3.19	56.6%	12.97	35.8%	2781.62	95.9%	25.21	0.94	4.1	871.7	7.9
4	0.56	60.2%	4.69	40.2%	211.89	99.7%	2.21	0.96	8.3	376.0	3.9
5	0.39	62.8%	4.28	44.3%	1.31	99.7%	0.49	0.96	10.9	3.3	1.3
6	0.39	65.3%	4.28	48.3%	1.31	99.7%	0.49	0.96	10.9	3.3	1.3
7	0.39	67.8%	4.28	52.4%	1.31	99.8%	0.49	0.97	10.9	3.3	1.3
8	0.39	70.3%	4.28	56.4%	1.31	99.8%	0.49	0.97	10.9	3.3	1.3
9	0.39	72.9%	4.27	60.5%	1.30	99.8%	0.49	0.97	10.9	3.3	1.2
10	0.39	75.4%	3.83	64.1%	1.40	99.8%	0.36	0.98	9.9	3.6	0.9
11	0.39	77.8%	3.82	67.7%	1.35	99.9%	0.35	0.98	9.9	3.5	0.9
12	0.39	80.3%	3.82	71.3%	1.34	99.9%	0.35	0.98	9.9	3.5	0.9
13	1.18	88.0%	11.72	82.4%	2.63	99.9%	1.07	0.99	9.9	2.2	0.9
14	1.87	100.0%	18.53	100.0%	3.33	100.0%	1.69	1.00	9.9	1.8	0.9
Total	15.54		105.55		5561.79		142.55				

Appendix A Table 28 Initial submittal 1992 General Aviation

Alt. Band (KM)	FUEL Kilograms (x10^9)	FUEL Cum. Fuel	NOX Grams (x10^9)	NOX Cum. NOX	CO Grams (x10^9)	CO Cum. CO	THC Grams (x10^9)	THC Cum. THC	Emission Index (EI) NOX	Emission Index (EI) CO	Emission Index (EI) THC
1	2.57	24.8%	9.90	17.1%	1338.48	23.5%	59.92	0.53	3.9	521.6	23.4
2	1.88	43.0%	7.69	30.4%	1368.73	47.5%	23.49	0.73	4.1	726.4	12.5
3	2.79	69.9%	9.58	47.0%	2761.47	95.9%	25.64	0.96	3.4	991.3	9.2
4	0.39	73.7%	2.66	51.5%	228.44	99.9%	2.24	0.98	6.8	581.2	5.7
5	0.20	75.6%	2.15	55.3%	0.23	99.9%	0.23	0.98	11.0	1.2	1.2
6	0.20	77.5%	2.16	59.0%	0.24	99.9%	0.24	0.98	11.0	1.2	1.2
7	0.20	79.4%	2.16	62.7%	0.24	99.9%	0.24	0.98	11.0	1.2	1.2
8	0.20	81.3%	2.16	66.5%	0.24	99.9%	0.24	0.98	11.0	1.2	1.2
9	0.20	83.2%	2.16	70.2%	0.24	99.9%	0.24	0.99	11.0	1.2	1.2
10	0.20	85.0%	1.93	73.5%	0.33	100.0%	0.18	0.99	9.9	1.7	0.9
11	0.20	86.9%	1.94	76.9%	0.33	100.0%	0.18	0.99	9.9	1.7	0.9
12	0.20	88.8%	1.94	80.2%	0.33	100.0%	0.18	0.99	9.9	1.7	0.9
13	0.47	93.4%	4.69	88.3%	0.81	100.0%	0.43	0.99	9.9	1.7	0.9
14	0.68	100.0%	6.75	100.0%	1.16	100.0%	0.61	1.00	9.9	1.7	0.9
Total	10.35		57.87		5701.26		114.04				

Appendix A Table 29 Initial submittal 1984 General Aviation

Alt. Band (KM)	FUEL Kilograms (x10^9)	Cum. Fuel	NOX Grams (x10^9)	Cum. NOX	CO Grams (x10^9)	Cum. CO	THC Grams (x10^9)	Cum. THC	Emission Index (EI) NOX	CO	THC
1	2.60	23.2%	9.89	15.6%	1373.13	21.8%	62.26	0.52	3.8	527.2	23.9
2	1.98	40.8%	8.16	28.4%	1472.49	45.1%	23.95	0.72	4.1	743.2	12.1
3	3.13	68.6%	10.56	45.0%	3213.87	96.1%	27.56	0.96	3.4	1026.1	8.8
4	0.42	72.3%	2.92	49.6%	238.76	99.9%	2.20	0.97	7.0	572.3	5.3
5	0.22	74.3%	2.45	53.4%	0.27	99.9%	0.27	0.98	11.0	1.2	1.2
6	0.22	76.3%	2.45	57.3%	0.27	99.9%	0.27	0.98	11.0	1.2	1.2
7	0.22	78.3%	2.45	61.2%	0.27	99.9%	0.27	0.98	11.0	1.2	1.2
8	0.22	80.2%	2.45	65.0%	0.27	99.9%	0.27	0.98	11.0	1.2	1.2
9	0.22	82.2%	2.45	68.9%	0.27	99.9%	0.27	0.98	11.0	1.2	1.2
10	0.22	84.2%	2.21	72.3%	0.38	100.0%	0.20	0.99	9.9	1.7	0.9
11	0.22	86.2%	2.21	75.8%	0.38	100.0%	0.20	0.99	9.9	1.7	0.9
12	0.22	88.2%	2.20	79.3%	0.38	100.0%	0.20	0.99	9.9	1.7	0.9
13	0.55	93.0%	5.40	87.8%	0.93	100.0%	0.49	0.99	9.9	1.7	0.9
14	0.79	100.0%	7.79	100.0%	1.34	100.0%	0.71	1.00	9.9	1.7	0.9
Total	11.25		63.59		6302.98		119.10				

Appendix A Table 30 Initial submittal 1976 General Aviation

Alt. Band (KM)	FUEL Kilograms (x10^9)	FUEL Cum. Fuel	NOX Grams (x10^9)	NOX Cum. NOX	CO Grams (x10^9)	CO Cum. CO	THC Grams (x10^9)	THC Cum. THC	Emission Index (EI) NOX	Emission Index (EI) CO	Emission Index (EI) THC
1	1.97	23.7%	7.50	16.7%	1107.15	21.8%	47.54	52.2%	3.8	560.6	24.1
2	1.49	41.6%	5.90	29.8%	1188.81	45.1%	17.16	71.1%	4.0	797.1	11.5
3	2.50	71.6%	8.21	48.1%	2597.57	96.2%	22.47	95.8%	3.3	1037.6	9.0
4	0.30	75.2%	2.00	52.6%	189.42	99.9%	1.73	97.7%	6.6	626.2	5.7
5	0.15	77.0%	1.63	56.2%	0.19	99.9%	0.18	97.9%	11.0	1.3	1.2
6	0.15	78.7%	1.63	59.8%	0.18	99.9%	0.18	98.1%	11.0	1.2	1.2
7	0.15	80.5%	1.63	63.4%	0.18	99.9%	0.18	98.3%	11.0	1.2	1.2
8	0.15	82.3%	1.63	67.1%	0.18	100.0%	0.18	98.5%	11.0	1.2	1.2
9	0.15	84.1%	1.62	70.7%	0.18	100.0%	0.18	98.7%	11.0	1.2	1.2
10	0.15	85.8%	1.46	73.9%	0.25	100.0%	0.13	98.8%	9.9	1.7	0.9
11	0.15	87.6%	1.46	77.2%	0.25	100.0%	0.13	99.0%	9.9	1.7	0.9
12	0.15	89.4%	1.46	80.4%	0.25	100.0%	0.13	99.1%	9.9	1.7	0.9
13	0.36	93.7%	3.59	88.4%	0.62	100.0%	0.33	99.5%	9.9	1.7	0.9
14	0.52	100.0%	5.19	100.0%	0.89	100.0%	0.47	100.0%	9.9	1.7	0.9
Total	8.34		44.90		5086.12		90.99				

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13. ABSTRACT (*Maximum 200 words*)
The report describes development of databases estimating aircraft engine exhaust emissions for the years 1976 and 1984 from global operations of Military, Charter, historic Soviet and Chinese, Unreported Domestic traffic, and General Aviation (GA). These databases were developed under the National Aeronautics and Space Administration's (NASA) Advanced Subsonic Assessment (AST) contract NAS1-20268, Task Assignment 14. McDonnell Douglas Corporation's (MDC), now part of the Boeing Company has previously estimated engine exhaust emissions' databases for the baseline year of 1992 and a 2015 forecast year scenario. Since their original creation, (Ward, 1994 and Metwally, 1995) revised technology algorithms have been developed. Additionally, GA databases have been created and all past MDC emission inventories have been updated to reflect the new technology algorithms. Revised data (Baughcum, 1996 and Baughcum, 1997) for the scheduled inventories have been used in this report to provide a comparison of the total aviation emission forecasts from various components. Global results of two historic years (1976 and 1984), a baseline year (1992) and a forecast year (2015) are presented. Since engine emissions are directly related to fuel usage, an overview of individual aviation annual global fuel use for each inventory component is also given in this report.

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